U.S. DEPARTMENT OF COMMERCE
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PB80-103997

Toxic Trace Metals in Mammalian Hair and Nails

National Inst of Scientific Research, Rancho Santa Fe, CA

Prepared for

Environmental Monitoring and Support Lab, Las Vegas, NV

Aug 79

United States
Environmental Protection
Agency

Environmental Monitoring
Systems Laboratory
P.O. Box 15027
Las Vegas NV 89114

EPA-600/4-79-049
August 1979

Research and Development

PB80-103997

EPA

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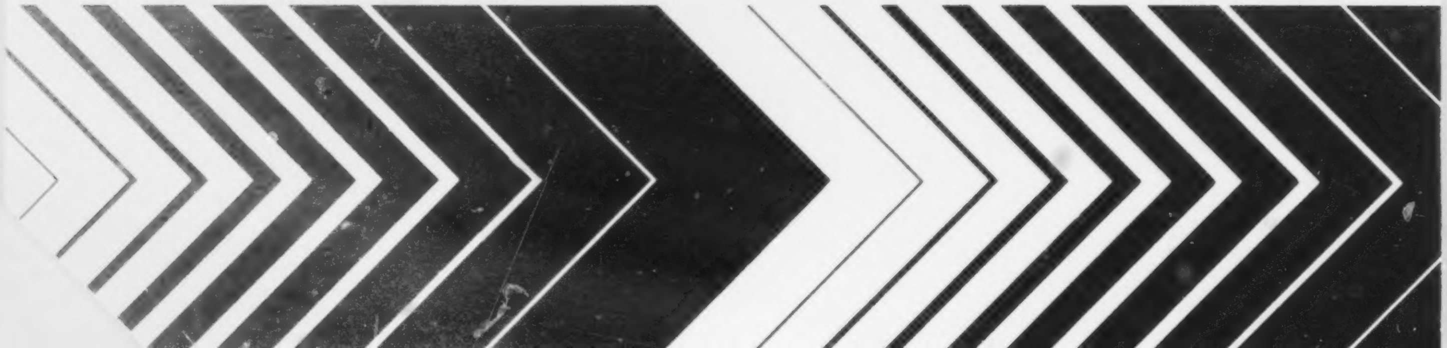

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TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-600/4-79-049	2.	3. RECIPIENT'S ACCESSION NO. PB80-103997

4. TITLE AND SUBTITLE TOXIC TRACE METALS IN MAMMALIAN HAIR AND NAILS	5. REPORT DATE August 1979 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Dale W. Jenkins	8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS National Institute of Scientific Research Rancho Santa Fe, Box 1617 California 92067	10. PROGRAM ELEMENT NO. 1HD775 11. CONTRACT/GRANT NO. 68-03-0443
12. SPONSORING AGENCY NAME AND ADDRESS U. S. Environmental Protection Agency-Las Vegas, NV Office of Research and Development Environmental Monitoring and Support Laboratory Las Vegas, NV 89114	13. TYPE OF REPORT AND PERIOD COVERED 14. SPONSORING AGENCY CODE EPA/600/07

15. SUPPLEMENTARY NOTES

For further information, contact the author at 3028 Tanglewood Drive,
Sarasota, Florida 33579

16. ABSTRACT

Data have been compiled from the available world literature on the accumulation and bioconcentration of selected toxic trace metals in human hair and nails and other mammalian hair, fur, nails, claws, and hoofs. The toxic trace metals and metalloids include antimony, arsenic, boron, cadmium, chromium, cobalt, copper, lead, mercury, nickel, selenium, tin, and vanadium. These have been tabulated by toxic metal, geographic area, subjects, sex, age, exposure gradient, analyses in ppm, and authority, from over 400 references. This compilation should provide background baseline reference information to help evaluate the usefulness of tissues for biological monitoring, and to help in the establishment of national or worldwide biological monitoring systems and networks.

The various uses of hair for biological monitoring are reviewed for correlating with environmental exposure gradients, diseases associated with excesses and deficiencies, geographic distribution, and historic trends. The advantages and disadvantages of using hair for biological monitoring are discussed. It appears to be that if hair and nail samples are collected, cleaned, and analyzed properly with the best analytical methods under controlled conditions by experienced personnel, the data are valid. Human hair and nails have been found to be meaningful and representative tissues for biological monitoring for most of these toxic metals.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Trace elements	Biological monitoring	57B, 57S

18. DISTRIBUTION STATEMENT RELEASE TO PUBLIC	19. SECURITY CLASS *(This Report)* UNCLASSIFIED	21. NO. OF PAGES 195
	20. SECURITY CLASS *(This page)* UNCLASSIFIED	22. PRICE PC A09 A01

EPA Form 2220-1 (9-73)

☆U.S. GOVERNMENT PRINTING OFFICE: 1979-683 091

EPA-600/4-79-049
August 1979

TOXIC TRACE METALS IN MAMMALIAN HAIR AND NAILS

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This report has been reviewed by the Environmental Monitoring and Support Laboratory-Las Vegas, U.S. Environmental Protection Agency, and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the U.S. Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

FOREWORD

Protection of the environment requires effective regulatory actions that are based on sound technical and scientific information. This information must include the quantitative description and linking of pollutant sources, transport mechanisms, interactions, and resulting effects on man and his environment. Because of the complexities involved, assessment of specific pollutants in the environment requires a total systems approach that transcends the media of air, water, and land. The Environmental Monitoring and Support Laboratory-Las Vegas contributes to the formation and enhancement of a sound monitoring data base for exposure assessment programs designed to:

- develop and optimize systems and strategies for monitoring pollutants and their impact on the environment

- demonstrate new monitoring systems and technologies by applying them to fulfill special monitoring needs of the Agency's operating programs.

This report is a compilation of the available world literature concerning the concentrations of selected trace elements in mammalian hair, fur, nails, claws, and hoofs. The compilation is intended to serve as reference information to assist in evaluating the usefulness of these tissues in biological monitoring. For further information contact the Monitoring Systems Research and Development Division, Environmental Monitoring and Support Laboratory, Las Vegas, Nevada.

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ACKNOWLEDGEMENTS

I express sincere appreciation to Mr. George B. Morgan, Director, Environmental Monitoring and Support Laboratory, U.S. Environmental Protection Agency, Las Vegas, for assistance in planning and conducting this study. Also, I wish to thank Dr. Richard E. Stanley, Deputy Director, for his interest and support.

The kind assistance of various libraries and data centers is gratefully acknowledged, especially the following:

Library, World Health Organization, Geneva, Switzerland

Libraries, Pan American Health Organization, Washington, D.C. and Mexico City

Libraries, U.S. Environmental Protection Agency, Las Vegas, Nevada, and Washington, D.C.

Library, National Research Council, Advisory Center on Toxicology, Washington, D.C.

Biomedical Sciences Section, Information Center Complex, Information Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee (especially Ms. Emily D. Copenhaver)

I am most grateful to my wife, Mrs. Joanne F. Jenkins, for excellent secretarial assistance.

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INTRODUCTION

Toxic trace elements are being released into the biosphere in ever-increasing quantities from more extensive burning of fossil fuels, more rapid industrialization with discharges from metallurgical and chemical plants, and more extensive use of chemicals. These trace elements and especially toxic heavy metals have reached levels that create a stressed environment. A study by Battelle Memorial Institute (Korte, 1974) of environmental stress indexes, showed that toxic metals are presently the second most important environmental nuisances that are hazards for "quality of life." These metals predominate in forecasts of future pollutant priorities.

Man himself is a central target for these toxic metallic elements, which normally occur in his body in relatively low concentrations. There is real danger of his exposure to chronic long-term low levels resulting in intoxication and diseased states, as well as exposure to accidental high levels with serious immediate results. A major problem would result if man became contaminated to levels giving rise to large-scale, harmful somatic or genetic effects (IAEA, 1977). It is, therefore, an urgent problem today to determine the initial or baseline levels of trace elements in man and the extent of his contamination in areas where he is exposed to contaminated food, water, and air, or occupational and other causes of exposure.

The problem of biological monitoring of levels of these trace elements in man is complex and difficult. The trace element distribution and composition of the whole body cannot be determined. If the critical organ concept is followed, it would be necessary to determine the concentration of trace elements in organs which can be critical (first producing symptoms or pathology) and then determine effective dose (as in the case of incorporated radionuclides (IAEA, 1977).

Biological monitoring is required to determine baseline levels, as well as the present extent of contamination. Certain trace elements are accumulated or bioconcentrated in various tissues of man and other mammals and offer a potential for biological monitoring. What is needed are tissues or substrates with trace element compositions that are fairly reliable indicators of contamination and easily accessible for chemical analysis.

Specific toxic metallic trace elements are bioconcentrated or accumulated in hair and nails of man and in hair, nails, claws, and hoofs of other mammals. These tissues can be sampled readily without injury to the host, and they have been used for relating to exposure to specific toxic metals. The Global Environmental Monitoring System (GEMS) of the United Nations Environment Program selected human hair as one of the important monitoring materials for world-wide biological monitoring.

The objective of the present report is to compile the available representative world literature on levels of selected toxic trace elements in hair and nails in man and in hair, nails, claws, and hoofs of other mammals. The compilation of data is comprehensive, but is not intended to be complete or exhaustive. These data should provide background baseline reference information to help evaluate the usefulness of these tissues for biological monitoring, and to help in establishment of national or worldwide biological monitoring systems and networks.

Thirteen trace metals and metalloids have been selected for review on the basis of various criteria, including relative toxicity, abundance, use, importance, and present and potential exposure of man and his food organisms. The selected metals or metalloids include: antimony (Sb), arsenic (As), boron (B), cadmium (Cd), chromium (Cr), cobalt (Co), copper (Cu), lead (Pb), mercury (Hg), nickel (Ni), selenium (Se), tin (Sn), and vanadium (V). Other metals, such as toxic beryllium (Be), are also of interest. There are almost no data available for Be in hair and nails.

Data on toxic metal accumulation and concentration in hair and nails, etc., have been compiled and presented in concise tabular form. The data are organized first for human hair and nails, followed by animal hair, nails, claws, and hoofs. The tables are then organized by toxic metal, with the geographic area, number of subjects sampled, sex, age, exposure or gradient, occupation, diet, and other factors, analyses in ppm with the range shown in parentheses followed by the average and by the standard deviation or standard error (if determined), and the authority and year. Some reports do not present details on sex, age, and other important sample collection factors, making interpretation of the data more difficult.

Data on uses of human hair have been compiled and reviewed. This review includes use of hair for biological monitoring, for correlation with environmental exposure gradients, for occupational exposure, and for diseases of pathology correlated with excesses or deficiencies of selected trace elements. Use of human hair is discussed with regard to geographic distributions and variation in distribution of trace elements. Studies are also reviewed with regard to historic trends in levels of certain trace elements using dated historic hair samples in comparison with present day samples. The use of human hair in forensic medicine is briefly discussed, including identification and timing of poisoning and hair individualization studies for identification.

Sample collection, preparation, and analysis are of importance in interpretation of the validity of data. In sample collection of human hair, there are a number of factors which may affect the results. These include location and type of hair, age, sex, hair color, and distance from the scalp and concentration variation along the shaft of hair. Data have been compiled and evaluated for each of these factors with regard to sample collection. Sample preparation, including washing and use of chemicals for removal of external contamination, is briefly discussed. The field of chemical analysis is highly complex and sophisticated. This subject is outside of the scope of this report; however, its importance is recognized and some critical reviews of analytical methodology are referenced.

The advantages and disadvantages of using hair as a tissue for biological monitoring are discussed. The consensus of most workers in the field is that if hair samples are collected properly, cleaned and prepared for analysis correctly, and analyzed by the best analytical methods using standards and blanks, as required, in a clean and reliable laboratory by experienced personnel, the data are reliable. These caveats would cast doubt on some data, especially earlier determinations using methodology and analytical apparatus, that do not compare with present sophisticated analyses.

Examination of the tabular data in Appendix A entitled "Compilation of Reference Data on Hair and Nails in Human Beings," shows that for specific uses, human hair is a meaningful and representative tissue for antimony, arsenic, cadmium, chromium, copper, lead, mercury, nickel, vanadium, and perhaps selenium and tin. However, for boron and cobalt human hair is either not meaningful or has not been studied sufficiently.

USES OF HUMAN HAIR AND NAIL MEASUREMENTS

GENERAL COMMENTS

There is extensive literature on the use of human hair (and some for nails) for biological measurement of trace elements. Concentration levels of the selected trace metals in human hair have been determined in nearly all regions of the world, with various monitoring or other objectives (see Table 1). Studies have been reported, including: 1) biological monitoring for correlation with environmental exposure gradients (from smelters, mines, highways, and other sources); 2) occupational exposure levels; 3) disease and physiologic or pathologic effects of nutritional excesses or deficiencies; 4) geographic distribution and variation; 5) historical trends; and 6) forensic medicine. These and other data have been compiled in tables in the appendices. The data for each of the major uses are summarized and discussed briefly.

BIOLOGICAL MONITORING FOR CORRELATION WITH ENVIRONMENTAL EXPOSURE GRADIENTS

Human and animal hair has been extensively analyzed to show correlation with exposure to environmental gradients of certain trace elements. These environmental gradients result from the production of high concentrations of one or more toxic trace elements from a single source or combined sources. These include gradients resulting from urban industrialized areas, refineries and petrochemical complexes, smelters for Pb, Cd, As, Cu, and Zn mines and mills, thermal power plants, and special manufacturing or special uses of trace elements. Data from various studies have been reviewed and the results are presented in Table 2 for human hair and in Table 4 for animal hair. Correlations with environmental gradients are indicated according to designations used by the research investigators as yes/no, or high/low. In some cases the correlation is indicated by a number showing the ratio of concentrations of metal in hair of exposed individuals (near the source) as compared with the concentration in hair of unexposed "controls," i.e., hair samples at the lower end of the environmental gradient at the greatest distance from the source. The sampling of adults or children is also indicated.

Examination of the summary in Table 2 shows high correlation between concentration of As in human hair with environmental exposure gradients for As for children, and for adults in two cases. For Sb in hair, one study showed some correlation. For Cd in hair, there are mixed results, varying

TABLE 1. MONITORING OF TOXIC METALS IN HUMAN HAIR AND NAILS IN VARIOUS REGIONS OF THE WORLD

	Sb	As	Cd	Cr	Co	Cu	Pb	Hg	Ni	Se	Sn	V
Canada	G,S	G,O,S W	G,S	S	G,S	O	G,O,W S	S,O,W G	G,S	G,S		
United States	S,H	G,O,H	G,O,S	G,S,H	S,H	G,S,H	G,O,W H,N	G,O,F H,N	G,O,H	G,S,H	G	G,S,H
Central America		W					G,S,O	G,S,O		G		
South America	S	S,W		S	S	S		S	S	S,G		S,N
Great Britain		G,O,S H				G,S,N	G,O	O,G,S F,H				
Europe	S	G,O,H S	O		S	S	G,O,W	G,S,F O	O	S,O		
Middle East	S			S	S	G	O,F	O,F,S		S		
Africa	O						O	S				
S. E. Asia		O,S				S	S	F,S				
Australia and New Zealand	S	S				S	O,S	S		S		

(Continued)

TABLE 1. MONITORING OF TOXIC METALS IN HUMAN HAIR AND NAILS IN VARIOUS REGIONS OF THE WORLD (Continued)

	Sb	As	Cd	Cr	Co	Cu	Pb	Hg	Ni	Se	Sn	V
Japan	S	G,S	F,W	S		S	G,O	G,S,F O				S
New Guinea, Samoa					N			F				N

Monitoring Objectives: G - Environmental gradient; O - Occupational exposure; S - Sampling base line;
F - Food; W - Water; H - Historical; N - Nails

TABLE 2. CORRELATION OF TOXIC METALS IN HUMAN HAIR WITH ENVIRONMENTAL EXPOSURE GRADIENTS

Environmental Exposure Gradient	Toxic Trace Elements										Authority
	As	Sb	Cd	Cr	Cu	Pb	Hg	Ni	Sn	V	
Urban to rural gradient, New York		No	No	Yes C	No	Yes C&A	Yes C&A	Yes C	Yes C	Yes C&A	Creason et al., (1975)
Urban to rural gradient, Panama						5-9X C&A					Klevay (1973)
Urban with refineries to rural, Canada	2.8X C&A	1.8X C&A	3.4X C&A			5X C&A	2.3X C&A	3.6X C&A			Chattopadyhay & Jervis (1974)
Pb & Zn smelter town to non-smelter, U.S.	High C		High C		No C	High C					Hammer et al., (1971,1972a)
Pb, Cd, & As gradient in cities, Montana	12X C		2.2X C		No C	5.8X C					Hammer et al., (1972b)
Cu smelter gradient, U.S.	High C		Low C		Low C	Low C					Hammer et al., (1971,1972a)
Cu smelter gradient, Washington	16X C										Milham & Strong (1974)
Smelter, Japan	6X C										Suzuki et al., (1974)
Pb processing plant, Germany						3.1X A					Aurand & Sonneborn (1973)
Zn and Cu mine mill rural vs. urban, Ireland	17.5X C				No C	No C	No C				Corridan (1974)
Urban petrochemical complex vs. rural, Texas N.H.						1.4X A&C					Eads & Lambdin (1973)
Thermal power plant, Czechoslovakia	3.5X C										Bencko (1966, 1970)
Na arsenite mfg. exposure gradient, Great Britain	8X A										Hill & Faning (1948)
Gradient from golf course using $CdCl_2$ New York			High A								Keil et al. (1975)

High, Low, Yes or No = Degree of correlation
(No.) X = ratio of exposed over control

C = Children
A = Adults

from high to low correlations for children exposed to smelters, with one high correlation for adults exposed to Cd used on a golf course, and some correlation between an urban area with refineries and rural gradient. Cr in hair was studied only for correlation with one urban to rural gradient and a positive correlation was found for children, but not for adults. For Cu in hair, five studies showed no correlation with environmental exposure gradients, except a low correlation for children from a Cu smelter gradient. For Pb in hair, there was a high correlation with urban to rural gradients in hair of both adults and children, a high correlation with a Pb and Zn smelter gradient in hair of children, but low correlation with a Cu smelter gradient and no correlation with a Zn and Cu mine and mill. There was a high correlation in adult hair with a Pb processing plant gradient, and in hair of adults and children with an urban petrochemical complex gradient, compared with rural. Hg in hair showed a correlation in both adults and children with urban to rural gradients, but no correlation in children with a Zn and Cu mine and mill gradient. For Ni and Sn in hair, a correlation was shown in children, but not in adults with an urban to rural gradient. For Ni, there was a correlation between urban with refineries and rural, for both adults and children. For V in hair, a correlation was found in both adults and children in one study with an urban to rural gradient.

A detailed study (Table 3) was made in Canada and eight trace elements in human hair were compared with degree of exposure in rural, urban, and urban near refineries (Chattopadhyay and Jervis, 1974, and Roberts et al., 1974a, b). This study shows that there were slight to greatly increased levels of As, Cd, Hg, Ni, Pb, and Sb in an urban area with refineries compared with a rural area. There was no significant increase for Co and Se between rural populations and urban near refineries.

In studies of animal hair high correlations, shown in Table 4, were found for As in cow and horse hair with a Cu smelter gradient, and for rabbit fur with a power plant gradient. For Cd, a high correlation was found in horse manes, with a Cu smelter gradient and in cow hair, with a Pb smelter gradient. For Cr, a high correlation was found in cotton rat hair with drift from a cooling tower. For Cu, no correlation was found. For Pb, there was a high correlation in horse manes with a Cu smelter gradient and a very high correlation in cow hair with a Pb smelter gradient. For Hg, there was a correlation in rabbit fur with an Hg mine and plant gradient, and some correlation in various animals with Hg in mineralized areas.

These studies show that hair from humans and other mammals can be used effectively to show correlations with environmental exposure gradients for specific trace elements. They also show the importance of age in using hair from children as compared with adults, since children are more effective for biological monitoring. Many other studies could be included, such as persons exposed to eating fish (high Hg) or occupational exposures for various metals, since they show high correlation with exposure, as compared with unexposed "controls," but these do not show a geographical environmental

TABLE 3. CORRELATION OF TOXIC ELEMENT CONTENTS IN HAIR OF POPULATIONS WITH DIFFERENT EXPOSURE LEVELS

	Rural 76 persons	Urban 45 persons	Urban near Refineries 121 persons
As	(0.45-1.7)0.68	(0.4-2.1)0.75	(0.63-4.9)1.9
Cd	(0.25-2.7)1.2	(0.32-3.4)2.0	(0.45-8.2)4.1
Co	(0.12-1.8)0.41	(0.15-2.6)0.48	(0.10-3.3)0.5
Hg	(0.28-3.5)1.2	(0.24-5.2)2.0	(0.2-5.5)2.3
Ni	(1.6-17.0)2.1	(1.2-20.0)2.4	(1.1-32.0)3.6
Pb	(0.5-25.0)9.1	(0.5-35.0)15.3	(10.0-350.0)45.3
Sb	(1.3-24.0)7.9	(1.5-33.0)9.7	(1.8-47.0)14.6
Se	(0.32-4.8)1.8	(0.29-6.3)1.9	(0.27-7.4)2.3

(Range) and median are presented in ppm

After Chattapadhyay and Jervis (1974)
Roberts et al. (1974a & b)

TABLE 4. CORRELATION OF TOXIC METALS IN ANIMAL HAIR WITH ENVIRONMENTAL EXPOSURE GRADIENTS

Environmental Exposure Gradient	Locality	Toxic Trace Elements As	Cd	Cr	Cu	Pb	Hg	Authority
Cu smelter Horse manes	Montana	14X	8-30X			10-25X		Lewis (1972)
Cu smelter Cow hair	Washington	20X						Orheim et al. (1974)
Pb smelter Cow hair	Missouri		12X		no	75X		Dorn et al. (1974)
Hg mine & plant Rabbit fur	Yugoslavia						1.7X	Byrne et al. (1971)
Drift from cooling tower Cotton rat hair & pelt	Tennessee			11X				Taylor et al. (1975)
Hg mineralized areas Antelope, big-horn sheep, coyotes and rodents	Idaho and Wyoming						yes	Huckabee et al (1972,1973)
Power plant Rabbit fur	Czechoslovakia	yes						Bencko (1970)

exposure gradient, so that they were not included in this review. Some of the correlation studies were excellent, with valid statistical sampling and critical statistical evaluation, while others were not as carefully controlled and evaluated.

In summary, human hair has been found to be of value for correlating human exposure to environmental gradients for arsenic, antimony, cadmium, lead, mercury, nickel, and vanadium, and, for children only, for chromium and tin. Boron and copper in hair were not found to be correlated with environmental gradients. Animal hair was of value for correlating exposure to environmental gradients for arsenic, cadmium, chromium, lead, and mercury, but not for copper.

OCCUPATIONAL AND ACCIDENTAL EXPOSURE

People can be exposed to toxic trace metals as an occupational hazard or by an accident. In breathing and by touching or ingesting, workers undergo a long-term, low-level dose or a brief, high-level exposure. Accidents would include eating mercury-contaminated food, like fish and shellfish, bread made from treated seed or pigs fed contaminated grain. These doses may result in toxic symptons or death. Biological monitoring is required to determine how much metal was absorbed and to attempt to measure exposure.

Blood and urine samples have been used far more extensively than hair or nails for determining exposure to toxic metallic trace elements. For very recent exposures, blood and urine are excellent for certain toxic metals. However, for measurement of levels of toxic metals for long periods or especially of exposure to a dangerously high level during a past period, hair appears to be superior to blood and urine for certain toxic elements concentrated in the hair. A comparison is presented for concentrations of trace elements in human blood and hair in Table 5. It should be pointed out that "normal" levels in blood and "normal" levels in hair are not agreed upon by experts, and various authorities will present different data. In this comparison, levels in hair presented by Gordus et al. (1974) and a summary from the present report are compared with blood. Various studies show lack of correlation between levels in blood and hair, especially after a lapse of time after exposure. Studies have also been conducted on using nails, bone, liver, kidneys, and other tissues (dependent on specific trace metal accumulation or bioconcentration) for determining absorbed dosage of trace metals.

Reported levels of toxic trace metals in human hair are presented in Table 6. The reported range and normal ranges are shown, together with levels of threshold effects and acute or chronic effects and death, where these are known. These data are tentative estimates and the information is incomplete. Again, it should be pointed out that experts do not agree on the interpretation of the data. This area requires much analysis and especially more critical data evaluation. It is hoped that this compilation, bringing together diverse data, will aid in determining "normal" or baseline levels, as well as those causing effects in humans.

Before discussing data on occupational exposure to toxic trace elements in relation to levels in human hair, the time of occurrence of the elements in hair should be considered. For chronic exposures over a long time, hair is usually suitable. For studies immediately after acute exposures, urine

TABLE 5. COMPARISON OF TRACE ELEMENT CONTENT OF HUMAN BLOOD AND HAIR (ppm)

	Blood (a)	Hair (b)	Hair (c)
Antimony	0.005	0.2	0.03-9.0
Arsenic	0.7	0.2	0.0-2.0
Boron	0.09		0.02-0.08
Cadmium	0.009	1.0	0.1-3.0
Chromium	0.003	1.0	0.0-4.0
Cobalt	0.0005	0.04	0.0-1.0
Copper	1.5	15.0	7.8-120.0
Lead	0.4	4.0	0.0-70.0
Mercury	0.005	1.5	0.01-30.0
Nickel	0.03	3.0	0.0-11.0
Selenium	0.2	0.8	0.3-13.0
Tin	0.015	1.0	1.0
Vanadium	0.02	0.03	0.006-1.0

a. Tinker (1971)
b. Gordus et al. (1974)
c. Tentative range of "normal" levels in this report. This is poorly defined and not agreed upon by experts (see Table 6).

and blood samples may be preferable. The toxic elements appear in the blood at intervals of time later and, for a short exposure, may appear only in a small segment of the hair correlated with the time of exposure. Analysis of the first two mm. of the root end (Henley et al., 1977) should correlate well with the concentrations of trace elements in blood.

TABLE 6. REPORTED LEVELS OF TOXIC METALS IN HUMAN HAIR AND TENTATIVE "NORMAL" AND TOXIC* LEVELS (ppm)

	Reported Range	"Normal" Range	Threshold Effects	Acute or Chronic Effects	Death
Antimony	0.03-47.0	0.03-24.0(a)	Unknown		
Arsenic	0.0-1,585.0	0.0-2.0	3.0	12.0	
Cadmium	0.1-9.3	0.1-3.0(b)	Levels not correlated with toxicity		
Chromium	0.0-6.43	0.0-4.0	Unknown		
Cobalt	0.0-3.11	0.0-1.0	Unknown		
Copper	7.8-486.0	7.8-120.0	Unknown		
Lead	0.0-1,880.0	0.0-70.0	12.5 infant 70.0 in children(c)		94.7-124.0
Mercury	0.01-2,436.0	0.01-30.0	50.0-200.0	200.0-800.0	500.0+
Nickel	0.0-15.6	0.0-11.0	Unknown		
Selenium	0.3-30.0	0.3-13.0	8.0-30.0	8.0-30.0	
Vanadium	0.006-271	0.006-2.71	Unknown		

*Levels are tentative estimates from visual inspection of data only. Data are incomplete on toxic effects, and experts vary in interpretation.

(a) Most below 9.0
(b) One Cd worker with 1,000.0
(c) Exposed adults frequently over 100.0 with no symptoms

The correlation levels of toxic metals with time after ingestion or exposure are of importance. In studies feeding ^{204}Pb, the peak occurred in facial hair in three male subjects about 125 days after start of feeding and about 35 days after the peak of blood ^{204}Pb (Rabinowitz et al., 1976). In Pb tracer studies in rabbits, Pb in hair began to increase 2-4 weeks after symptoms of Pb poisoning occurred and continued to increase 2 months after discontinuation of dosage. Arsenic has been found in the hair as early as 30 hours and as late as 9 years after ingestion (in Kyle, 1970). The As appears in hair soon after ingestion, is transported even to hair tips, and the As levels remain elevated in hair months after exposure (Shapiro, 1967). In women acutely poisoned with Hg, there is a slightly prolonged period of maximum Hg concentration and a delayed disappearance from the hair (Giovanoli-Jakubczak and Berg, 1974). Mercury is deposited in hair following exposure and on termination of exposure, the level in hair drops. This fact was used to trace the history and extent of exposures of people to methyl mercury, taking into account the growth rate (Giovanoli-Jakubczak and Berg, 1974) and dating exposure to Hg in a swimming pool (Martz and Larson, 1973).

In late 1971 and early 1972 an outbreak of alkylmercury poisoning occurred in Iraq due to use of Hg-treated wheat seed to make bread. Mean maximum hair Hg levels were 136.0±S.E. 17.8 ppm for 413 persons who ate contaminated bread, compared with 5.0±S.E. 0.8 ppm for 1,012 persons who had not, or 27.2x the unexposed. The mean blood levels were 0.034±S.E. 0.005 µg/ml for those who ate contaminated bread compared with 0.007±S.E. 0.0009 µg/ml for those who had not, or 4.8x the unexposed. These persons were over 5 years of age (Kazantzis et al., 1976a).

Eleven women who showed severe mercury poisoning with disability had mean maximum mercury hair levels of 400.0 ppm. Nineteen women with mild or moderate disability had Hg hair levels of 209.0 ppm (Kazantzis et al., 1976b).

The concentration of mercury in hair was correlated with illness, by Al-Shahristani et al. (1976). Peak mercury concentrations of 1.0-300.0 ppm were found in persons who consumed Hg-contaminated bread but showed no symptoms, corresponding to an average body burden of 10 µg to 2.2 mg Hg/kg of body weight. People with mild symptoms had peak Hg hair concentrations of 120.0-600.0 ppm, corresponding to an average body concentration of 0.8-4.4 mg Hg/kg of body weight. Moderate symptoms were observed in persons with peak Hg concentrations in hair of 200.0-800.0 ppm, corresponding to an average body concentration of 1.5-6.0 mg Hg/kg of body weight. Persons with severe symptoms had peak Hg hair concentrations of 400.0-1,600.0 ppm, corresponding to average body concentration of 3.0-12.0 mg Hg/kg of body weight.

Human hair has been used to determine levels of toxic trace elements in an attempt to determine absorbed dose from occupational exposure. Comparisons have been made between trace element concentrations in hair of occupationally exposed workers and "controls" or "normals" (Table 7).

Antimony mine workers have been shown to have extremely high levels of Sb in the hair; however, the threshold and toxic levels are unknown.

Arsenic in hair has been studied for persons exposed to manufacture and use of arsenic products, including people in mines and smelters. Comparisons have been made with unexposed "controls" showing significant differences.

TABLE 7. COMPARISON OF TRACE ELEMENT CONCENTRATIONS IN HUMAN HAIR OF OCCUPATIONALLY EXPOSED VS. "CONTROLS"

	Exposed	"Controls"	Authority
Antimony			
Sb mine workers	1,000.0		Rodier & Souchere (1957)
Arsenic			
Mfg. of sodium-arsenite	108.0	13.0	Hill & Faning (1948)
Lab. using detergent shampoo	42.0		Lenihan et al. (1958)
Industrial occup. exp. to dust	>300.0	2.0	Polson & Tattersall (1969)
As mine workers	to 1,000.0		Van den Berg et al. (1969)
As production	(15.0-237.0)91.0	(0.01-0.35)0.15±S.D. 0.34	Dale et al. (1975)
Sn smelting	(2.2-753.0)88.0	(0.01-0.35)0.15±S.D. 0.34	Dale et al. (1975)
Agr. workers using As	(0.8-11.4)7.2	(0.01-0.35)0.15±S.D. 0.34	Dale et al. (1975)
Cadmium			
Cd workers	>1,000.0		Nishiyama & Nordberg (1972)
Lead			
Policemen	132.5		Speizer et al. (1973)
Policemen on motorcycles	183.3		Speizer et al. (1973)
Lead workers	51.7		Barry (1972)
Uranium miners ^{210}Pb	1.42 pCi/g	0.034 pCi/g	Jaworowski (1964)
Lead workers	>110.0	>30.0	Suzuki et al. (1958)
Lead battery workers	217.3		Nishiyama et al. (1957)
Rayon manufacture	168.1		Nishiyama et al. (1957)
Printing office - male	106.4		Nishiyama et al. (1957)
Printing office - female	116.3		Nishiyama et al. (1957)
Printers & metal workers	32.8	10.4	Reeves et al. (1975)

(Continued)

TABLE 7. COMPARISON OF TRACE ELEMENT CONCENTRATIONS IN HUMAN HAIR OF OCCUPATIONALLY EXPOSED VS. "CONTROLS" (Continued)

	Exposed	"Controls"	Authority
Mercury			
Dentists	1.0-34.0	2.5	Gutenmann et al. (1973)
Occupational exp. to Hg	5.0-10.0	0.2-6.0	Jervis et al. (1970)
Hg smelter workers	3.0-48.85	1.9	De la Pina (1975)
Fishermen	27.6-46.6		Tejning (1970)
Hg smelter workers	25.0	1.8	Cigna Rossi et al. (1976)
Inhaled Hg vapors	20.4	1.9-6.2	Ota (1966)
Tungsten refinery workers	10.1	4.2	Akitake (1969)
Dentists	9.8		Ohno et al. (1967)
Tunafishermen	19.9-45.0		Yamanaka et al. (1972)
Dental assistants	10.1±S.D. 15.0	3.38±S.D. 3.4	Lenihan & Dale (1976)
Smelter workers	25.0±S.D. 6.1	1.8 ±S.D. 0.4	Clemente (1976) & Cagnetti et al. (1974)
Hg miners	4.0±S.D. 0.8	1.8 ±S.D. 0.4	Clemente (1976) & Cagnetti et al. (1974)
Nickel			
Nickel workers exposed to Ni carbonyl	4.0-4.81	(0.5-1.0)	Hagedorn-Götz et al. (1977)

Cadmium in hair has not been studied sufficiently with regard to occupational exposure.

Lead in hair has been studied in relation to persons occupationally exposed to lead, including policemen, lead metal workers in battery and rayon manufacture, and printing office workers. Lead workers, uranium miners, and printers showed high levels in comparison to "controls."

Mercury in hair has been studied for dentists, dental assistants, mercury smelter workers, tungsten refinery workers, industrial workers, and tuna fishermen. Dentists, Hg smelter workers, and tungsten refinery workers had high levels of Hg in hair in comparison with hair of "controls."

Nickel in hair was studied in nickel workers exposed to Ni carbonyl in an accident and were compared with unexposed "controls."

DISEASE CORRELATED WITH EXCESS AND DEFICIENCY

Hair and nails may be of value for diagnosing or correlating levels of trace metals with disease states. Various diseases or deficiency states caused by 14 selected toxic metals are shown in Table 8. These data have been summarized from information by Schroeder and Nason (1971) on "Trace-Element Analysis in Clinical Chemistry" and the data compiled in this report. Hair and nails have already been used to diagnose some of these diseases and could be of value for additional diseases related to specific toxic metals.

Other researchers have correlated concentrations of toxic elements with disease. These correlations are described starting on page 19.

TABLE 8. POSSIBLE CLINICAL USE OF HAIR AND NAILS FOR HELPING DIAGNOSE OR INDICATE DISEASE OR DEFICIENCY STATES (Schroeder and Nason 1971)

Antimony -- toxic to humans and animals

Arsenic -- arsenite is toxic; arsenical polyneuritis

Beryllium -- toxic; causes cancer of lung

Boron -- low toxicity to mammals

Cadmium -- toxic; causes arterial hypertension, pregnancy toxemia, itai-itai disease; is most insidious and widespread health hazard; causes congenital abnormalities

Chromium -- causes diabetes mellitus, cancer of lung; deficiency causes atherosclerosis, hypercholesteremia, hyperglycemia; accumulates in lung

Cobalt -- high Co implicated in myocardial insufficiency; may play a role in immune reactions

Copper -- absence of gene for Cu homeostasis causes hepatolenticular degeneration; high Cu implicated in various collagen diseases, rheumatoid arthritis, and infections

Lead -- toxic; lead poisoning, subclinical states from moderate level, with ill-defined asthenia, neurosis; mental retardation in children

Mercury -- methyl Hg is highly toxic; mercury poisoning, Minamata disease; causes congenital abnormalities

Nickel -- causes cancer of lung; in myocardial infarction Ni increases in blood; causes congenital abnormalities

Selenium -- essential element; excess causes alopecia; causes tumors

Tin -- toxic; accumulates in lung

Vanadium -- may have a role in cholesterol and fatty acid metabolism; accumulates in lung

Antimony. -- High levels of Sb in hair have been correlated with Sb toxicity in Sb miners (Rodier & Souchere, 1957).

Arsenic. -- High levels of As in hair have been correlated with As poisoning by various authorities. High As in fingernails and presence of white striae are said to usually be diagnostic of arsenical polyneuritis (Mees, 1919).

Cadmium. -- High Cd levels in hair are not usually correlated with toxicity and are not effective for clinical diagnosis of itai-itai disease.

Chromium. -- No available studies of Cr in hair have yet been correlated with excess or deficiency diseases of humans. Cr is lower in fingernails of atherosclerotic persons (Masironi, 1974), and periungal sites have been identified as sites of Cr ulcers (National Academy of Sciences, 1974).

Cobalt. -- No available studies of Co in hair or nails have yet been correlated with disease in humans.

Copper. -- Low Cu of hair has been associated with Menkes kinky hair syndrome (Singh & Bresman, 1973).

Lead. -- High levels of Pb in hair have been correlated with lead poisoning with various symptoms and death, by several authors. High Pb in hair was correlated with decreased elongation and strength of hair (Suzuki et al., 1958).

Mercury. - High levels of Hg in hair have been correlated with Hg poisoning with various symptoms (including blindness, convulsions and death) by many investigators.

Nickel. -- High concentrations of Ni in hair have been correlated with weak respiratory symptoms in an occupational accident (Hagedorn-Götz et al., 1977).

Selenium. -- High Se causes alopecia, loss of hair (Rosenfeld & Beath, 1964).

Tin. -- No available data on Sn in hair has been correlated with human disease.

Vanadium. -- High V in hair was correlated with decreased cystine of nails (Stokinger, 1963; Hudson, 1964; Mountain et al., 1955).

In summary, high levels of Sb, As, Pb, Ni, and Hg in hair have been correlated with toxicity or poisoning in humans. High levels of Se caused loss of hair and high levels of V decreased cystine. Low levels of Cu have been associated with Menkes kinky hair syndrome. No correlations with excess or deficiency diseases or conditions have been found in available reports for Cd, Co, and Sn.

GEOGRAPHIC DISTRIBUTION

The levels of trace elements in human hair may vary geographically if there is a high or low natural level of an element in an area, if the people are exposed to high levels from proximity to smelters, industry, etc., or from eating or drinking contaminated food or water. The elements are reviewed below to determine areas with levels significantly different.

Antimony -- The levels of Sb in human hair in the United States, Japan, and New Zealand are comparable. In Canada, Chattopadhyay and Jervis (1974) reported very high levels of Sb in hair in rural, urban, and urban areas near refineries. Levels of Sb in hair of antimony mine workers in Morocco were extremely high.

Arsenic -- Levels of As in hair were high in Mexico and Chile due to natural high levels of As in drinking water and were high around Cu, Pb, and Zn smelters or Cu and As mines in various countries, including the United States, Canada, Ireland, Scotland, Czechoslovakia, and Japan.

Cadmium -- The Cd level in hair is sometimes slightly correlated with higher levels of exposure, but there do not appear to be significant differences in levels with geographic areas.

Chromium -- The Cr level in hair in Venezuela and Iraq appears to be higher than in the United States, Canada, and Japan.

Cobalt -- The level of Co appears to be high in Venezuela.

Copper -- The data vary widely, but there do not appear to be any significant differences in Cu levels in human hair in the various countries.

Lead -- While no obvious differences in concentrations of Pb in human hair appear between countries, the United States, Canada, Panama, Great Britain, France, and Japan, and New Zealand report high levels correlated with proximity to large cities, occupational exposure, or other factors.

Mercury -- Ukita (1968) and Al-Shahristani and Al-Haddad (1972) characterized average "normal" levels of Hg in hair as 4.0-6.0 ppm in North America and most European countries, 6.0-8.0 ppm in Japan, and 1.0 in Iraq. It appears that few countries have "normal" hair levels higher than average, but high levels occur in many countries, which can be ascribed to eating fish or grain with high levels of Hg, or exposure to smelters or occupational exposure.

Nickel -- Levels of Ni in hair of Amazonian Indians in Venezuela are more than 10 times the average levels in the United States, Canada, or Germany.

Selenium -- There is a significant difference in level of Se in human hair from high and low Se areas within the United States and in Central and South America (Rosenfeld and Beath, 1964). Levels were fairly high in Venezuela and Iraq.

Tin -- Data only in the United States.

Vanadium -- No significant differences in geographical levels of V in hair were observed.

In summary, there are significantly higher levels in human hair of As in Mexico and Chile due to naturally high levels of As in water, and higher or lower levels of Se correlated with natural excesses or deficiencies in various regions of North and South America. Other differences, such as high levels of Hg, are correlated with high intake of Hg-contaminated fish and proximity to contamination. Co, Cr, Ni, and Se levels were high in Venezuelan Indians. For As and Pb there are high levels correlated with pollution and occupational exposure.

There are insufficient data for human nails and from animal hair, nails, claws, and hoofs to make geographical comparisons.

HISTORIC TRENDS IN TRACE ELEMENTS IN HAIR

Preserved hair and bones have been used to compare levels of certain trace elements in humans over historic periods to determine possible trends (Table 9). Antique hair samples were frequently saved by many Americans and Europeans, with locks of hair (usually female) encased in lockets, airtight boxes or woven in floral designs which frequently were preserved without known contamination. The dates of preservation and the ages of the females were often recorded.

Concentrations of lead were studied by Weiss et al. (1972) in historic and contemporary hair samples. Hair samples from 36 children (under 16 yrs. of age) from 1871-1923 averaged 164.24±S.E. 20.7 ppm compared with 16.23±S.E. 0.97 ppm from 119 children's hair samples in 1971. Historic samples are 10.12 times contemporary samples and significant at $P = < 0.01$ using a t test. Hair samples from 20 adults from 1871-1923 averaged 93.36±S.E. 16.3 ppm compared with 28 adult hair samples in 1971 with 6.55±S.E. 1.17 ppm. Historic samples are 14.36 times higher than contemporary samples and significant at $P = < 0.01$ using a t test. This study is confirmed by Gordus et al. (1974), who found median levels of lead in 3 female hair samples in the 1800's to be 1,250.0 ppm, in 13 female hair samples from 1900 to 1930 to be 106.0 ppm, and in 20 males in 1971 to be 4.1 ppm. This finding is 304.8 times levels in present hair, comparing with young men, or 77 times, comparing with children in 1971. The results by Weiss et al. (1972) were discussed by Locheretz (1973). There are problems in attempting to correlate exposure to Pb and levels in hair since in historic times hair was washed less frequently, and external contamination may have occurred during storage of some samples. However, the lead levels have decreased so greatly from historic to present times that the data are probably valid. Lead was commonly used for cosmetics, for kitchen utensils, water conduits, and other purposes so that exposure levels were higher despite present higher atmospheric and street dust levels in the environment (Jenkins, 1972).

Comparison of the trace element concentrations in historic hair samples, up to 200 years old, with modern samples based on geometric means in female scalp hair (Table 9) shows that there has been an increase in Cu, Ni, and V and a decrease in Sb, As, Cr, and perhaps Hg. If comparisons are made between the historic female sample medians and 1971 male medians, there has been an increase in Cd and a great decrease in Pb (Gordus et al., 1974, 1975).

Arsenic shows a significant decrease in two studies (Table 9), a drop that is probably correlated with decreased use of arsenical medicines and germicides and with substitution of DDT and other pesticides for lead arsenate and paris green (Jenkins, 1972, 1976).

The increase in V and small increases of Ni, Cd, and Cu in modern hair is probably correlated with actual increase in exposure to these elements (Gordus et al., 1975). Even for those trace elements which show little increase or decrease, there may have been an increase in exposure in the last 100 years. As stated above, hair was probably washed less in historical times than modern, and historic samples are often clippings of distal ends which for Cu have higher levels than proximal ends. The possible contamination of historic samples must be considered, but some samples are known to have been sealed or protected from contamination. With these caveats, the most significant changes in trace element levels in hair appear to be a significant increase in V and a significant decrease in As and Pb.

FORENSIC MEDICINE

Forensic medicine is a highly complex specialized field and no attempt is made to review it here since it is mainly outside of the scope of this report. However, the data in this field contribute knowledge on levels of toxic trace metals in hair and nails. In forensic science, hair and nails are used extensively to attempt to demonstrate, prove, and to date poisoning and exposure to various toxic metals, especially arsenic, cadmium, chromium, lead, mercury, and nickel.

Abnormal concentrations of trace elements, such as As and Hg in hair, have served in a number of investigations as an evidence of ingestion of abnormal amounts of toxic substances (Lenihan and Smith, 1959; Forshufvud et al., 1961; Smith, 1964; and Shapiro, 1967). The concentration along the

TABLE 9. COMPARISON OF CONCENTRATIONS OF TRACE ELEMENTS IN HISTORIC AND CONTEMPORARY HUMAN HAIR SAMPLES (in ppm)

	1890 Female		1890-1910 Female		1910-1935 Female		1972 Female	1971 Male	After Gordus et al. (1974, 1975)
	Geom. Mean	Med.	Geom. Mean	Med.	Geom. Mean	Med.	Geom. Mean	Med.	Comparison of Means
Antimony	.476	.5	.779	.63	.507	.63	.084	.154	decrease by 5.66x
Arsenic	2.5	5.2	1.5	0.8	1.2	0.8	0.4	.14	decrease by 62.5x
Cadmium		.21		.53		.53		.47	(increase by 2.24x in. medians)
Cobalt	.125	.13	.069	.053	.054	.053	.106	.037	no significant change
Chromium	2.4	2.6	3.8	3.2	3.9	3.2	1.4	1.5	decrease by 1.7x
Copper	13.	18.	12.	12.	11.	12.	21.	16.	increase by 1.6x
Lead		1250.		106.		106.		4.1	(decrease by 304.8x in medians)
Mercury	3.5	3.6	1.8	2.0	1.6	2.0	2.8	1.8	decrease by 1.25x
Nickel	3.1	2.7	2.5	3.2	4.0	3.2	6.3	3.1	increase by 2x
Selenium	.62	.58	.47	.55	.62	.55	.54	.67	no significant change
Vanadium	.014	.009	.02	.006	.016	.006	.054	.024	increase by 3.86x

	1790-1849 Geom. mean	1850-1899 Geom. mean	1900-1949 Geom. mean	1973-1974 Geom. mean	After Dale et al. (1975)
Arsenic	3.81	3.74	0.78	0.13	decrease by 29.3x
Mercury	3.62	6.14	1.27	2.41	decrease by 1.5x

	1871-1923 Average	1971 Average	After Weiss et al. (1972)
Lead-adults	93.36	6.5	decrease by 14.36x
Lead-children	164.24	16.23	decrease by 10.12x

length of the hair can be used to reveal the history of the poisoning (see section below on Concentration Variation in Hair in Relation to Distance from Scalp). The pattern of concentration variation of Hg along hair was shown to be a more reliable criterion for hair individualization identification than average concentration values (Al-Shahristani and Al-Haddad, 1972; Bate, 1966). Perkons and Jervis (1962) found large differences occurred in samples of the same individual over several years.

Hair is being studied for use of trace element concentrations for hair individualization and identification in a manner similar to identification by fingerprint analysis. There are many problems in hair individualization analyses. Nails are also used in forensic science to determine poisoning and evidence of ingestion of abnormal amounts of toxic trace elements, such as arsenic.

HAIR SAMPLE COLLECTION, PREPARATION AND ANALYSIS

SAMPLE COLLECTION

Statistical considerations of biological monitoring of human hair should include the human target populations at risk, for example, around sources, such as smelters, mines, local high concentrations in soil and water supply, urban areas, including metal processing industry, manufacturing areas, and populations at risk from occupational exposure and eating contaminated foods. It is also necessary to monitor unexposed human control populations in rural and isolated areas to determine background baseline levels. For many of these trace elements there are now regional baseline or control data to compare with exposed populations at risk. These data should be validated by statistical evaluation requirements for additional data determined. Until this is accomplished, the magnitude of a proposed monitoring program is still subject to the outcome of the evaluation.

The optimal descriptive information required for each individual sample includes the following:

1. Age, sex, race, skin, and hair color.
2. Occupation, length of time in occupation, other occupational history.
3. Exposure to toxic metals.
   a) Urban or rural
   b) Occupational special exposure
   c) Hobbies, vacations, special foods, water, use of pottery, smoking habits
   d) Cosmetics, hair care, washing frequencies, dyes
   e) Environment -- live near smelters, mines, traffic, metal industries, etc.
4. Hair sample -- location on scalp or elsewhere, distance from scalp, how collected, date, amount.

5. Special remarks -- disease, alopecia, skin, or other disorders, illness, hospital or medical history, if applicable. Living or dead, cause of death, if applicable.

6. Special remarks -- e.g., socioeconomic group, education.

It is necessary to agree on an international standardization of the size of hair sample, location on body or location on scalp, distance from scalp, and length of hair.

LOCATION AND TYPE OF HUMAN HAIR ON THE BODY

Human hair has been analyzed from the scalp, facial beard, axillary, chest, and pubic areas. This is important with regard to evaluating external contamination, particularly of the exposed scalp. In addition, various areas of scalp hair have been evaluated and the nape of the neck has been stated to be least exposed to external contamination.

All human hair data in this report are for scalp hair, except data quoted below. Levels of some elements have been correlated between scalp and pubic hair and between scalp and axillary hair as shown in Table 10.

There is significantly less Cu, Hg, and Pb in pubic hair than in scalp hair for the few comparisons made. One comparison made between scalp and axillary hair showed axillary hair to be 2.5 times greater than scalp hair, which may be due to perspiration contamination, but there are insufficient data to make a valid comparison. Factors, such as growth rate, distal vs. proximal hair and other factors in addition to contamination, must be evaluated before valid comparisons can be made.

Facial beard hair has been used for determining As in a hospitalized case poisoned from As containing sheep dip. The beard hair decreased from 3.12 ppm weekly to 1.79 to 0.84 and 0.94. No comparison was made with scalp hair (Lenihan & Smith, 1959). Beard hair of three 25-to 53-year-old males with no occupational exposure had (13.2-16.0)14.7 ppm, but no comparison was made with scalp hair (Rabinowitz et al., 1976). Se was found in beard hair of a man using Se medication (23.0 ppm) (Fuller et al., 1967).

AGE

Differences in trace element levels in human hair have been reported correlated with age. This has resulted in many research workers selecting children instead of adults for studying trace element levels in hair.

TABLE 10. COMPARISON OF CONCENTRATIONS OF TRACE ELEMENTS IN SCALP, PUBIC, AND AXILLARY HAIR (in ppm)

		Scalp	Pubic	
Gu	50 Ohio females	(17.3-18.4)17.9	(12.8-13.2)13.0	Baumslag et al., (1974)
Pb	50 Ohio females	(30.0-33.0)31.5	(16.0-17.2)16.6	Baumslag et al., (1974)
	Black females	49.3	21.8	Baumslag et al., (1974)
	White females	15.5	9.1	Baumslag et al., (1974)
Hg	"Normal", no known exposure	5.5	1.6	Rodger & Smith (1967)
Hg	46 dental technicians, Scotland	10.1±S.D. 15.0	4.14±S.D. 4.80	Dale et al. (1975)
Hg	Kenyans using Hg skin lightening cream within 6 mos. of sampling	(20.5-9,220.0)2108.0	(5.2-1,470)335.0	Dale et al. (1975)
Hg	Kenyans discontinuing using Hg skin lightening creams more than 6 mos. prior to sampling	(2.768.0)137.0	(4.2-1,490.0)159.0	Dale et al. (1975)
Hg	Kenyans who never used Hg creams	(0.5-23.4)11.0	(0-85.0)18.4	Dale et al. (1975)
		Scalp	Axillary	
Pb	Yugoslavia, fatal case ate Pb-concentrated flour	4.0	10.0	Danilovic (1958)

Antimony - Ohmori et al. (1975) found no significant difference (1.1 ratio) in Sb in hair of age ≥20 years (0.068) in comparison with <20 years (0.061 ppm).

Arsenic -- There was more (1.5 times) As in hair of age ≥20 years (0.095 ppm) as compared with age <20 years (0.063 ppm) according to Ohmori et al. (1975).

Cadmium -- There was a decrease in Cd levels from younger females 1-30 years (2.59±0.379 ppm) to older females 40 to 70 years (0.92±0.153 ppm) with (P = <0.001, t = 3.87). There was a decline in Cd in females after age 70. Grey hair depigmentation was also correlated with low Cd (Schroeder and Nason, 1969). Eads and Lambdin (1973) found no difference in Cd hair levels in young and old aged males, but there was a decline in levels in female hair in subjects aged 37 to 72 years. Petering et al. (1973) found that Cd levels increased in male hair with age up to 20 years and then decreased slightly. In females, Cd levels increased in hair up to a peak at age 40 to 50 years and then decreased slightly, but the level remained high. Keil et al. (1975) showed an increase in Cd in hair with age.

Chromium -- Concentrations of Cr in hair in men did not decline with age and was maintained in women after age 40 (Schroeder and Nason, 1969). Cr levels in hair of 3-8 month infants was significantly higher than in 2 to 3 year old children (Hambidge and Rodgerson, 1969). There was no difference (ratio 1.0) in Cr in hair of ≥20 years (0.6 ppm) in comparison with <20 years (0.6 ppm) according to Ohmori et al. (1975).

Cobalt -- The level of Co in hair in men did not decline with age and was maintained in women after age 40 (Schroeder and Nason, 1969).

Copper -- There was a decrease in Cu levels in hair from younger females 1-30 years (86.2±16.67 ppm) to older females 40-70 years (16.6±1.58 ppm) with (P = <0.001, t = 3.89). The level of Cu in hair in men did not decline with age (Schroeder and Nason, 1969). Eads and Lambdin (1973) did not find any change of Cu levels in hair correlated with age in males, but there was a decline of Cu in female hair of subjects from age 37 to 72. Hair samples from persons <40 years were not significantly different from samples >40 years (Hutchinson et al., 1974). There was less Cu (ratio 0.78) in age >20 years (9.3 ppm) than in age <40 years (12.0 ppm) according to Ohmori et al. (1975).

Lead -- There was a decrease in Pb levels from younger females 1-30 years (24.5±4.90 ppm) to older women 40-70 years (8.4±1.16 ppm) with (P = <0.001, t = 3.76). Pb did not accumulate with age in men (Schroeder and Nason, 1969). Eads and Lambdin (1973) found there was no significant change of Pb with age in males, but there was a decline in Pb with age in female hair in subjects aged 37-72 years. Weiss et al. (1972) found a significant decrease in levels of Pb in hair of children under 16 years (16.23±0.97 ppm) to adults over 16 years (6.5±1.17 ppm) with significance P = <0.01, and in antique hair

(1871-1923) from children under 16 years (164.24±20.7 ppm) to adults over 16 years (93.36±16.3) with significance P = <0.01. Lead in human hair in age groups 1-21, 22-42, 43-87 years did not show any significant differences of the means for any age groups at the 90% confidence level (Reeves et al., 1975). In Panama, Klevay (1973) found a significant decrease with age in Pb levels in hair of males, but not females. Petering et al. (1973) found a decrease in levels of Pb in hair of males, and in female hair found an increase up to age 35 and then a sharp decrease.

Mercury -- There was no age difference correlation in Hg levels of hair in men, but there was a decline of Hg in female hair in subjects aged 37-70 years (Eads and Lambdin, 1973). There was no difference in Hg levels in hair correlated with age (Giovanoli-Jakubczak, 1974). In females, the Hg level in hair increased to a maximum in age group 41-60 years and decreased slightly after 61 years. In males, the maximum Hg level was in age group 11-20 years and decreased slightly after 21 years (Benson and Gabica, 1972).

Nickel -- There was no increase in Ni in hair with age (Schroeder and Nason, 1969). There was a fairly uniform distribution of Ni levels in both males and females in different age groups (Eads & Lambdin, 1973).

Vanadium -- Ohmori et al. (1975) found less V (ratio 0.62) in age $\geq$20 years (0.021 ppm) than in age <20 years (0.034 ppm).

In summary, there was no significant change in levels of antimony, chromium, cobalt, and nickel with age. There were usually decreases in levels of Cd and Cu with age in females, but no decreases in males. There was an increase in As with age over 20 years in one study. For lead, the results are mixed, but in general there were more decreases found in levels of Pb in hair for both present and historic samples. For mercury, the results are mixed for the three studies reported. There was a decrease of V with age over 20 years, in one study.

SEX

Differences in trace element levels have been reported between male and female hair samples by some authors, as summarized in Table 11 and below:

Antimony -- Coleman et al. (1967) showed higher levels of Sb in male than female hair, but possible age differences were not evaluated. There was slightly more (1.3 times) Sb in female (0.071 ppm) than in male hair (0.055) (Ohmori et al., 1975).

Arsenic -- Levels of As were significantly higher in male hair than in female in a population of over 1,000 samples (Lenihan & Smith, 1959). There was no significant difference between As levels in college age males and females (Gordus et al., 1974, 1975). Arsenic was appreciably higher in male

TABLE 11. CORRELATION OF TRACE ELEMENT CONTENT OF HAIR WITH SEX (in ppm)

	Female	Male	Signif.	Author
Sb		Higher		Coleman et al. (1967)
	0.071 geom. mean	0.055 geom. mean	1.3x	Ohmori et al. (1975)
As	0.11 geom. mean	0.048 geom. mean	2.3x	Ohmori et al. (1975)
		Signif. higher		Lenihan & Smith (1959)
	No significant difference (col. age)		0	Gordus et al.(1974,1975)
Cd	No significant difference		0	Eads & Lambdin (1973)
	Higher, 40-50 yrs.			Petering et al. (1973)
	No significant difference		0	Schroeder & Nason (1969)
		gray hair higher		Schroeder & Nason (1969)
Co	0.28±S.D. 0.043	0.17±S.D. 0.482	P=<0.02 t=2.32	Schroeder & Nason (1969)
Cr	0.6 geom. mean	0.6 geom. mean	1.0x	Ohmori et al. (1975)
	No significant difference		0	Schroeder & Nason (1969)
	No significant difference		0	Coleman et al. (1967)
Cu	13.0	9.4	1.4x	Ohmori et al. (1975)
	55.6±S.D. 10.27	16.1±S.D. 1.19	P=<0.001 t=4.86	Schroeder & Nason (1969)
	No significant difference		0	Eads & Lambdin (1973)
Pb	34.6 mean	24.5 mean		Klevay (1973)
	17.9 med.	11.4 med.		Klevay (1973)
	19.0	17.8		Schroeder & Nason (1969)
	higher age 35-50			Petering et al. (1973)
	higher			Shabel'nik (1968)
	No significant difference		0	Reeves et al. (1975)
	No significant difference		0	Eads & Lambdin (1973)
Hg	5.9	2.45	1.6-3.2X	Benson & Gabica (1972)
	No significant difference		0	Eads & Lambdin (1973)
	No significant difference		0	Nord et al. (1973)
Ni	4.09±S.D. 1.091	1.07±S.D. 0.178		Schroeder & Nason (1969)
	No significant difference		0	Eads & Lambdin (1973)
V	0.025 geom. mean.	0.026 geom.mean	0.96x	Ohmori et al. (1975)

than in female hair (cited in Gordus et al., 1974). Ohmori et al. (1975) found 2.3 times more As in female (0.11 ppm) than in male hair (0.048 ppm).

Cadmium -- There were no significant differences in Cd levels between males and females (Eads and Lambdin, 1973). There was a significantly higher level of Cd in 40-50 year old females than in similar males (Petering et al., 1973). There were no significant differences in Cd levels between males and females, but grey hair of women had less Cd than male grey hair (Schroeder and Nason, 1969).

Chromium -- There was no significant difference between Cr levels in male and female hair (Schroeder and Nason, 1969). Coleman et al. (1967) showed similar Cr levels in male and female hair. Ohmori et al. (1975) found 0.6 ppm Cr in both male and female hair.

Cobalt -- Female hair averaged 0.28±0.043 ppm, while male hair had 0.17± 0.483 ppm. The female hair was significantly more contaminated ($P = <0.02$, $t = 2.32$) than the male, according to Schroeder and Nason (1969).

Copper -- Schroeder and Nason (1969) found Cu levels in female hair higher than in male hair. The females averaged 55.6±10.27 ppm and male 16.1±1.19 ppm ($P = <0.001$, $t = 4.86$). No significant differences in Cu levels were found between male and female hair by Eads and Lambdin (1973). Ohmori et al. (1975) found 1.4 times more Cu in female (13.0 ppm) than in male hair (9.4 ppm).

Lead -- Klevay (1973) in Panama found that Pb in female hair was significantly higher (17.9 ppm median, 34.6 ppm mean) than male hair (11.4 ppm median, 24.5 ppm mean), with age and geographic location taken into account. Kraut & Weber (1944) found a mean level of Pb of 19.2 ppm for females and 14.7 ppm for males ($P = <0.001$, $t = 3.38$). No significant difference was found by Schroeder & Nason (1969) between Pb levels in females (19.0 ppm) compared with males (17.8 ppm). Petering et al. (1973) found higher Pb levels in females than males 35-50 years old. Shabel'nik (1968) found higher Pb levels in female hair than in male hair. Reeves et al. (1975) did not find significant differences between female and male Pb hair levels. Eads and Lambdin (1973) did not find significant Pb level differences between males and females.

Mercury -- The mean level of Hg in female hair was 5.90 ppm and in male hair was 2.45 ppm. Females had 1.6 to 3.2 times higher Hg levels than males, based on hair from over 1,000 residents in Idaho (Benson & Gabica, 1972). No significant difference was found between levels of Hg in male and female hair by Eads and Lambdin (1973). Nord et al. (1973) found no difference in Hg levels between male and female hair samples.

Nickel -- There was more Ni in natural colored hair of females (4.09±1.091 ppm) than similar hair in males (1.07±0.178 ppm), Schroeder and Nason (1969). Eads and Lambdin (1973) found no significant difference in Ni levels between female and male.

Vanadium - There was no significant difference in V (0.96 times) between female (0.025 ppm) and male hair (0.026 ppm), according to Ohmori et al. (1975).

It is difficult to summarize the effect of sex on levels of trace elements because age differences and distance from scalp were not always considered. In general, there were higher levels of Cd, Co, Cu, Pb, Hg, and Ni in female hair, but there were also reports of no difference between sexes for Cd, Cr, Cu, Pb, Hg, Ni, and V. Until more critical studies including the effect of other factors are carried out, it is difficult to find clear-cut differences based on sex.

HAIR COLOR

In comparing levels of trace elements with hair color, a few differences have been found, particularly in female hair that has become depigmented, where there is less Cu, Cd, and Pb, but this is not true of men's grey hair. There is also less Cd in black hair and perhaps more Ni in red than brown hair.

Arsenic -- Comparisons were made of As in black, brown, blonde, and grey hair by Schroeder and Balassa (1966), and no significant differences were found in the few samples tested.

Cadmium -- No significant correlation was found by Eads and Lambdin (1973) between levels of Cd and hair color. There was significantly less Cd in grey-haired females than in natural colored female hair or in grey-haired males. Young female hair had higher levels of Cd than hair from older women. In males, there was less Cd in black hair than in hair of other colors (Schroeder and Nason, 1969).

Chromium -- Schroeder and Nason (1971) found 0.69±0.062 ppm in 48 males with natural hair color and 0.73±0.148 ppm in 14 males with grey and white hair. Five females with grey and white hair had 0.96±0.049 ppm and nine males with red hair had 0.39±0.048 ppm. In comparisons with larger populations, there does not appear to be any significant differences between hair colors.

Cobalt -- Schroeder and Nason (1969) and Schroeder et al. (1967) compared single samples of red, black, and white hair from different ages and sexes so no comparison can be made.

Copper -- Kikkawa et al. (1958) reported higher levels of Cu in pigmented than white hair, and Eads and Lambdin (1973) found a high Zn/Cu ratio for dark hair. Anke and Schneider (1962), comparing 22 males and females, found levels of Cu were slightly higher in black than in brown, blonde, grey, or white hair. Schroeder and Nason (1969) found grey-haired females had significantly lower levels of Cu than those with natural colored hair. However, this was not found in males, so it is unlikely to be associated with greying. Cu may be absorbed externally on hair.

Lead -- Eads and Lambdin (1973) found no significant differences in lead levels related to hair color. Schroeder and Nason (1969) found lower levels of Pb in grey-haired females (but not in males) than in those with pigmented hair.

Mercury -- No differences in Hg levels were found in relation to hair color by Eads and Lambdin (1973).

Nickel -- No differences were found in Ni levels in relation to hair color by Eads and Lambdin (1973). Schroeder and Nason (1969) found that natural colored hair of females had more Ni than natural colored hair of males and more Ni in red than brown hair.

Selenium -- Schroeder et al. (1970) compared Se levels in brown, red, grey, and black and white hair but found no significant differences in the few samples tested.

CONCENTRATION VARIATION IN HAIR IN RELATION TO DISTANCE FROM SCALP

Variation in concentration of trace elements along the shaft of the hair from the scalp outwards is extremely important in collection of hair samples. Scalp hair grows at a rate of about 1 cm per month, an average of 50-100 strands of hair are lost per day, and the average person has about 100,000 strands of scalp hair (Gordus et al., 1974). Growth rate of hair ranges from 0.75 to 1.35 cm/mo. and is influenced by age, sex, and pregnancy (in Giovanoli-Jakubczak, 1974). Growth rate of hair was also calculated using mercury exposure. Growth rate of adult hair is 0.3 mm/day or about 1 cm per month (Snyder et al. 1974), and the rate for the newborn is 0.2 mm/day, increasing to 0.3-0.5 mm/day.

Two millimeter lengths of root ends of human hairs have been analyzed by Henley et al. (1977). These should reflect the most recent internal milieu and correlate closely with blood as well as exclude externally adhered constituents, such as those of hair treatment and atmospheric pollutants. Copper and chromium have been analyzed by this technique.

Variation in concentration of trace elements along the shaft of the hair has been studied for antimony, arsenic, cadmium, chromium, cobalt, copper, lead, mercury, nickel, and selenium (Table 12). For these metals, the concentration at specific sites along the hair appears to be correlated with time of exposure. However, for copper it appears that it is concentrated at the distal ends of the hair. Research data on concentration variation in hair are summarized for these metals.

Arsenic -- In a case of subacute poisoning of several weeks duration, the greatest amount of arsenic was in the proximal 5 cm. and from one-tenth to one-twentieth less in the more distal parts of the hair. Al-Shahristani and Al-Haddad (1972) state that As, once introduced into the hair through metabolic functions, appears to be fixed and is not affected by washing or perspiration. In a study of arsenic content of hair in acute arsenic

TABLE 12. VARIATION OF TRACE ELEMENT CONCENTRATION IN HAIR IN RELATION TO DISTANCE FROM SCALP (in ppm)

	Length of Hair (in cm)							Authority
	1	11	21	31	41	51	61	
Sb	0.033	0.03	0.027	0.038	0.063			Obrusnik et al. (1973)
Cd	0.15	0.35						Parker et al. (1973)
Cr	1.8	11.4	1.0	0.5	1.0			Obrusnik et al. (1973)
Co	0.5	1.0	1.5	2.0	2.7			Obrusnik et al. (1973)
Cu	15.0	---	---	63.0				Renshaw et al. (1973)
Cu	15.0		50.0					Gordus et al. (1975)
Cu	30.0	50.0	80.0					Gordus et al. (1975)
Cu	36.0	40.0	54.0	52.0	62.0	65.0	110.0	Gangadharan & Sankar Das (1976)
Hg	1.7	2.3	2.7	3.0	5.2			Obrusnik et al. (1973)
Hg	30.0	50.0	30.0	250.0	850.0			Gangadharan & Sankar Das (1976)
Hg	12.0	200.0	5.0					Al-Shahristani & Shibab (1974)
Hg	10.0	350.0	5.0					Clarkson (1977)
Hg	8.0	6.0	14.0					Al-Shahristani & Al-Haddad (1972)
Hg	6.0	6.0	4.0					Al-Shahristani & Al-Haddad (1972)
Pb	6.86	13.65						Dresch & Fortman (1976)
Ni	0.4	39.9						Hagerdorn-Götz et al. (1977)
Se	5.0	33.0	70.0	80.0	83.0			Obrusnik et al. (1973)

poisoning, it was found that arsenic appears in sweat soon after ingestion and that sweat can carry the dissolved poison along the hair shafts where the arsenic can bind with the sulfur in hair (Lander et al., 1965).

Cadmium -- Cadmium was measured at 0.5 cm intervals along the shaft of washed hair. Cd averaged 0.1 to 0.2 ppm in the basal half and increased to 0.3 to 0.4 at 11 to 13 cm in the distal part. This measurement was not correlated with any known exposure history. Parker et al. (1973) stated that a profile of Cd concentration along the hair can be determined and that the concentration of Cd in the hair is an indication of the total amount of Cd ingested. It is not known whether Cd accumulates at the distal end of the hair or whether these measurements were correlated with previous exposure.

Chromium -- Cr levels in hair changed with increasing distance from hair roots (Hambidge et al., 1972a).

Copper -- Hair samples from males and females aged 18 to 22 years showed a significant increase in Cu from the basal to the distal parts of the hair shaft (Gordus et al., 1975). Some of the more pronounced variations were 30 to 80 ppm and 15 to 50 ppm from the proximal to the distal end. It was proposed that this difference may be due to exposure to sweat, but this was not proven. Bate and Dyer (1965) found an increase in concentration of Cu from the scalp to the distal end by about a factor of two. Renshaw et al. (1973) showed that in a 30-cm sample of hair from a female, the proximal part was 15.0 ppm while the distal ends were 64.0 ppm. In 17 females and 40 males, the Cu levels increased from the root to the tip with greater variation at the distal end.

Lead -- As hair grows from the scalp, the concentration of lead is relatively constant, if exposure is continuous. When exposure is episodic, division of hair into sections permits detection of episodes of previous lead exposure. Kopito et al. (1969) found good correlation between hair lead concentration and increased body stores in lead-exposed children. However, Barry (1972) found poor correlation between hair lead levels and blood lead content. This finding could be due to the sampling distance from the scalp in relation to time of exposure or to external contamination. Studies have shown that the concentration of lead in the hair is an indication of the total amount of metal ingested, so that long after blood and urine concentrations have returned to normal, the evidence of even a brief exposure is stored in the hair (Kopito et al., 1967).

Much higher lead levels in the proximal segment were taken as evidence of abnormal lead intake during a period of several weeks prior to sampling. Suzuki et al. (1958) found that, with increased Pb absorption, Pb content increased, and elongation and strength of hair decreased.

Mercury -- The concentration variation along the length of hair can be used to reveal the history of Hg poisoning. The pattern of concentration variation along hair was shown to be a more reliable criterion for hair individualization identification than average concentration values

(Al-Shahristani and Al-Haddad, 1972). Hair growth rate is not constant over the scalp, and peaks of concentrations do not appear at exactly the same distance from the root; however, the relative positions of the peaks are very consistent for the same individual regardless of the growth rate.

The distribution of a peak concentration of Hg along hair shafts correlated with high exposure to Hg in women who ate Hg-contaminated wheat in bread (Gio-vanoli-Jakubczak and Berg, 1974) (Giovanoli-Jakubczak et al., 1974). In the long hair of female subjects from Iraq who had eaten the bread, the date of exposure could be determined by a peak in Hg concentration. The levels of Hg in hair of females who had eaten Hg-contaminated bread in Iraq is shown in Figure 1. The peak levels were correlated with the time of initiating eating the bread, 14.5 months before taking hair samples, and with the accumulation period. The rate of growth of hair was 1.13 cm mo. The points on the curve are the mean of a large number of subjects, e.g., 2.5 cm value for 250 persons, 7.5 cm for 210, and 12.5 cm for 133 persons (Kazantizis et al., 1976a).

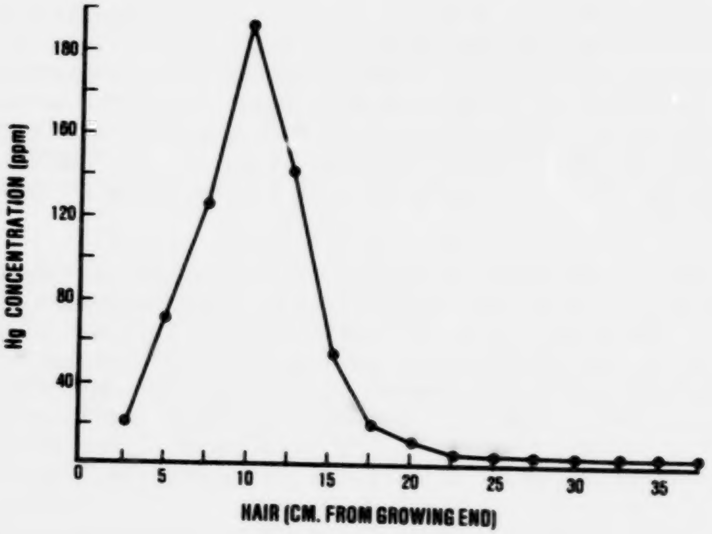

Figure 1. Mercury concentration distribution along hair shafts in high exposure individuals.

Dating of mercury exposure 18 months earlier was done by Martz and Larsen (1973) in girls with hair over 30 cm in length. Benson and Gabica (1972) state that in measuring Hg in hair, the terminal end of hair 45 cm in length would represent the Hg body burden experienced 12-18 months previously. Analysis of segments of long hair enabled determination of the peak period of Hg intake (Irukayama, 1966). In persons who had inhaled Hg vapors, the hair near the scalp was 20.4 ppm and decreased 7 months later to 4.6 ppm (Ota, 1966).

Nickel -- Nickel levels were dated back to nearly one half of a year. The half life of Ni in the body was approximately calculated from hair analyses and was in the same order of magnitude found in the turnover of Ni in serum. The relative concentration of Ni in hair of 3 persons (Table 13) dropped from about 48-28 ppm to about 4.0 ppm in 50 days and to about 0.4 ppm in 160 days (Hagedorn-Götz et al., 1977).

CLEANING AND SAMPLE PREPARATION

Chemical analysis of toxic trace element levels of biological samples always requires consideration of the possibility of any contamination from external or other sources. Hair surface can be contaminated from hair dyes, shampoos, soaps, cosmetics, free oils, hair sprays, and lacquers, as well as dirt and dust from hands and from the atmosphere.

The cleaning procedures that have been developed by various investigators are diverse and no standardized method has been used. A critical review of the effectiveness of the various methods is outside the scope of this report. However, the importance of cleaning of external contamination of hair and nail samples is of importance for validity of results and for interpreting data, so that a brief discussion is presented on different methods and problems.

Most investigators wash hair samples with detergents, solvents, and/or other substances. In cases where scalp hair is suspected of being externally contaminated, especially in women's hair or occupationally exposed men, axillary or pubic (or chest or facial beard) samples can be compared with scalp hair (Table 10). Some investigators have recommended collection of scalp hair at the base of the neck, since the nape area may be less exposed to external chemicals. It has been recommended that hair samples be collected near the scalp with samples about 1.5 to 3.0 cm in length.

There has not been a standardized washing procedure for cleaning the external surface of hair (Wilson et al., 1974). Various procedures and combinations have been used, including organic solvents (Bate, 1965), anhydrous alcohol, ethyl ether, acetone, and carbon tetrachloride and boiling water, soaps and detergents (ionic or non-ionic), EDTA ethylenediamine tetraacetate (chelating agent), and dilute nitric acid. Only a few studies compare the effectiveness of the various agents to remove exogenous surface contamination without affecting the endogenous toxic metals. Wilson et al. (1974) found that some types of shampoo contain mercury additives that can apparently penetrate the lipid barrier of the hair to bind endogenously, directly with the sulfhydryl, thiol, or amino groups of the hair proteins. This has also been found for cadmium. This study shows that hair from any person with high levels of toxic metal who has not been exposed to a known source should always be held in suspicion, and pubic or axillary hair should be checked, and a sample taken from the nape of the neck (Sorenson and Petering, 1974). Also, long hair can be segmented and a determination can

TABLE 13. RECORD OF Ni CONCENTRATION IN HAIR OF THREE SUBJECTS AS A FUNCTION OF DAYS AFTER EXPOSURE

Subject 1		Subject 2		Subject 3	
Days	Ppm	Days	Ppm	Days	Ppm
0	48.1	0	39.9	0	28.0
14	7.4	10	11.5	13	7.5
27	10.5	19	5.0	24	4.9
40	1.6	28	4.9	36	5.0
53	4.0	38	3.3	49	7.0
66	1.4	47	4.0	62	3.3
79	<0.4	58	2.6	72	5.0
92	<0.4	67	3.7	85	9.2
105	0.8	76	2.8	99	3.9
118	2.7	85	2.5	108	4.1
131	0.8	94	2.4	117	2.6
144	0.8	104	2.0	133	<0.4
156	<0.4	113	2.0	145	<0.4
169	<0.4	123	2.0	160	0.9
		131	3.1		
		142	4.2		
		150	4.2		
		160	<0.4		
		169	<0.4		

Hair cut in 5mm lengths, in ppm (after Hagedorn-Götz et al., 1977) be made as to whether the metal content is continuous or discontinuous during the growth history of the hair. Sorenson and Petering (1974) recommend removing external contamination by using an acetone wash followed by an anionic detergent wash, such as sodium lauryl sulfate. Hammer et al. (1971) used multiple washing with detergent, distilled water, ethanol, and boiling EDTA solution. Lead was removed by the detergent (probably external contamination), none by ethanol, and some was removed by the EDTA solution. The effect of washing hair on trace element concentration before and after cutting is shown in Table 14.

A recommended standardized procedure for collecting and treating hair samples has been proposed by the International Atomic Energy Agency and the World Health Organization (IAEA/WHO 1975). The recommended standardized procedures for hair are:

> Hair sample should be taken from the occipital region of the head as close to the scalp as possible. A bundle of hair the size of a matchstick should be cut with special plastic scissors.
>
> The hair should be cleaned with Soxhlet extraction using diethyl ether for two hours. This removes the oxidized natural greases from the outside of the hair but has little effect on the major or minor elements in the hair itself.
>
> It is preferable that hair samples be stored under deep freeze conditions, but this is not required.

A recommended standardized procedure for collecting and treating toenails has also been proposed by the IAEA/WHO (1975). The recommended standardized procedures for toenails are:

> Population groups normally walking barefooted may pose an insuperable problem in relation to dirt accumulation on the toenails and should, therefore, be excluded from the study.
>
> At least 20 mg of toenail clippings should be collected using stainless steel scissors or nail clippers (any Cr or other contamination from stainless steel should be removed by washing). Scrape all visible dirt with scissors before cutting. Clippings from two big toes usually give a large enough sample, if each clipping is the full width of the toenail. If needed, include clippings from other toes.
>
> A washing solution of 90 parts absolute ethyl alcohol and 10 parts 30% H_2O_2 (in water) should be used. The nail samples should be placed in a 150 ml Ehrlemmeyer flask and washed 3 times with 30 ml volumes (each time) of the washing solution.

TABLE 14. EFFECT OF WASHING HAIR ON TRACE ELEMENT CONCENTRATION (ppm)

	Before Cutting (geom. mean)[a]		After Cutting[b]	
	Washed 20 or >x/mo.	Washed 2 or <x/mo.	Unwashed	Washed[c]
Sb			8.52	8.40
As	0.21	0.35	1.24	1.17
Cd	1.20	1.40	0.46	0.45
Co	0.19	0.13	0.36	0.34
Pb	3.10	7.70	47.30	45.10
Hg	2.10	3.10	1.63	1.58
Ni			3.22	3.10
Se	0.76	0.80	1.67	1.72
V	0.036	0.094		

a After Gordus et al. (1974)
b After Chattopadhyay (1974)
c Washed with distilled H_2O, absolute ethanol and ether

> Wash 2 minutes each time with gentle shaking and decanting. Tip the sample into a Hirsh funnel or carefully cleaned plastic funnel with quartz wool in the stem and wash with 10-20 ml of diethyl ether. The clippings should be removed with plastic forceps and dried in a suitably cleaned container for 10 minutes at 60-70°C. Subsequent analyses should be expressed in terms of dry weight.
>
> Toenail samples should preferably be stored under deep freeze conditions, but this is not required.

Cleaning of nails has been attempted using a variety of methods, including scraping, scraping and washing with ammonium barbituric acid buffer (Kanabrocki et al., 1968), use of Tween 80 and shaking and rinses (Goldblum et al., 1953), washing in Triton X-100 and shaking and rinses (Kile, 1954), scraping and washing in 0.1N HCl (Kopito et al., 1965), washing in distilled water and acetone (Petrushkov et al., 1969), and other methods with alcohol and acetone, in Teepol, in ether, 7X-0-matic, detergent and ethyl alcohol. It appears that scraping excess dirt from nails and use of a detergent is effective in removing any external metal contamination.

While there has been much debate in the literature on interpretation of data in relation to external contamination of hair and nails, the consensus of opinion is that these samples, when carefully collected and properly cleaned, provide valid and reliable analysis.

Sample preparation requires international agreement and standardization of collecting and washing procedures and detergents, organic solvents, and chelating agents. The international use of the standardized procedures proposed by IAEA/WHO will contribute greatly to obtaining valid results.

CHEMICAL ANALYSIS

Chemical analytical methodology of toxic trace metals is a broad, highly complex, and sophisticated field, which is changing as new and improved methods are developed. While the importance of evaluation of analytical methods is recognized in interpreting the validity of the data (especially older determinations), this is not within the scope of the present report and is left to analytical methodology experts.

Analytical methodology for toxic trace elements has been critically reviewed, both for the general field, and in detail for specific trace elements. In a general critical review for various trace metals, Lisk (1974) listed various analytical methods, including atomic absorption, anodic stripping, voltimetry, colorimetry, emission spectrometry, fluorescence analysis, gas-liquid chromatography, neutron activation analysis, and polarograpny.

Each metallic element requires a specific evaluation with regard to sensitivity, accuracy, precision, ranges of measurements, cost, convenience, and time with each analytical method. For example, analysis of cadmium has been evaluated by Fleischer et al. (1974) and in an unpublished review by Oak Ridge National Laboratory.

Accurate and optimal methods of chemical analysis should be agreed upon for each trace element and standardized analytical samples should be used. The results should be reported in standardized units, such as ppm or µg/g (preferably oven dry weights) and accuracy of analysis should be reported. The number of samples, range, average, arithmetic and geometric means, median, standard deviation, or standard error, and other statistical data and tests of significance should be reported as appropriate.

The International Atomic Energy Agency started a research project in 1975 on "Nuclear-based methods for analysis of pollutants in human hair." The nuclear-based analytical methods include: 1) Photon activation analysis, 2) Charged particle activation analysis, 3) Fast neutron activation analysis, 4) Proton-induced X-ray emission, and 5) Reactor neutron activation analysis. In addition to these accelerator-based analytical methods, other nuclear-based methods being used include: 6) ^{252}Cf activation analysis, 7) X-ray fluorescence analysis, 8) Emission spectrographic analysis, and 9) Atomic absorption spectrometry. The IAEA is coordinating the results of studies using these methods (IAEA, 1977).

ADVANTAGES AND DISADVANTAGES OF USING HAIR

There are advantages and disadvantages of using hair as a tissue for biological monitoring:

A. Advantages

1. Certain toxic metals accumulate or bioconcentrate in hair.
2. Some metals are retained and provide a linear historic record, over time, of the time and period of exposure (do not decrease as rapidly as in blood and urine after cessation of exposure). Hair and nails are stable and samples several hundred years old have been analyzed.
3. Samples are easily obtained by clipping hair from subjects, from barber shops, and using historic hair samples and other sources, with minimum legal problems.
4. Hair requires only plastic sacks or simple containers for storage.
5. Hair does not require dry ice or refrigeration for storage and transport.
6. Hair is easily transported and has little weight or volume.
7. Standardized methods can be made available for collecting hair samples.
8. Standardized methods can be made available for washing and preparation of samples.
9. Standardized methods are available for analysis and use of standards.
10. Storage of aliquots is simple for reanalysis and study of historic trends (no decomposition or changes reported).
11. For certain metals there is excellent correlation with environmental exposure gradients, e.g., distance from smelters, mines, and other sources.

12. For certain metals, as Se or As, there is good correlation with natural geographic occurrence.

13. For certain metals correlation with excess ord deficiency disease states is good.

14. For certain metals correlation with occupational exposure is excellent.

B. Disadvantages

1. External contamination of hair can be a source of error. This can come from hair dyes, shampoos, soaps, cosmetics, free oils, hair sprays, and lacquers, as well as dust and dirt from hands and the atmosphere.

2. In cases where external contamination of scalp hair is suspected, it may be necessary to compare scalp hair with axillary, pubic, chest, or face hair. Hair at the base of the scalp in the rear of the head (nape) has been recommended as the area probably least contaminated by external sources.

3. Washing procedures before analysis may affect the results for some metals depending on the procedure used. Detergents, organic solvents, and especially chelating agents remove various amounts of exogenous surface contamination. Standardized sample preparation procedures must be used.

4. The level of metals varies with distance from the scalp, depending on the exposure history. The distance of hair from the scalp must be measured and reported.

5. Levels of some trace elements in hair vary in relation to sex of the subjects.

6. Levels of some trace elements in hair vary with age of the subjects. Many investigators have found children of school age to be the best age group for sampling.

7. Levels of some trace elements in hair vary with type and location of hair on the body.

8. Levels of some trace elements in hair vary with hair color, but this is not as important as distance from scalp, type, and location of hair, age, and sex. All of these factors must be taken into account in sampling and design of experiments.

INTERNATIONAL MONITORING OF TRACE ELEMENTS IN HUMAN HAIR AND NAILS

A report on the Global Environmental Monitoring System (GEMS) written by a SCOPE committee recommended that the United Nations Environment Program utilize human hair as one of the important materials for biological monitoring. Hair was proposed in a world-wide monitoring network to indicate levels of trace metals in human beings.

The International Atomic Energy Agency became concerned with applications of nuclear methods for the analysis of trace pollutants in 1975. The first two research projects were "Neutron activation analysis of pollutants in human hair using research reactors", and "Accelerator-based techniques for the analysis of pollutants in human hair." These two projects are now being implemented as a research coordination program "Nuclear-based methods for analysis of pollutants in human hair." This is aimed at establishing patterns for contents of trace pollutants in human hair for the normal population in different geographic and economic regions and revealing groups or individuals with increased levels of the pollutants. This program has shown that the chemical composition of human hair reflects the exposure to many trace element pollutants. About 40 scientists from over 20 countries are participating in the program.

The IAEA and the World Health Organization have a joint research program on trace elements in cardiovascular diseases using hair and toenails. The recommendations from this program for collection and treatment of hair and nail samples was presented above in the section on Cleaning and Sample Preparation. Masironi et al. (1976) published a report in this program relating trace element concentrations in toenails with blood pressure in New Guinea villagers.

An International Workshop on Biological Specimen Collection was held in Luxembourg, 18-22 April 1977, sponsored by WHO, Commission of the European Communities and the U.S. Environmental Protection Agency. The use and value of hair as a biological monitoring material was discussed (Clarkson, 1977; Jenkins, 1977).

A coordinated world-wide biological monitoring program and network, using human hair and nails, by the GEMS program of UNEP with assistance and coordination from IAEA and WHO would be of great value in determining levels and trends of toxic trace metals in human beings.

APPENDIX A

COMPILATION OF REFERENCE DATA ON HAIR AND NAILS IN HUMAN BEINGS

This review of available world literature is intended to be comprehensive, but not complete or exhaustive in coverage. This field is expanding very rapidly and data are being published throughout the world literature, including a wide variety of scientific journals in disciplines in medicine, physiology, biology, and ecology, environment, chemical analysis, and forensic medicine. Data are also published in popular magazines, the press, proceedings of various meetings, critical reviews, contract and annual reports, and private and governmental reports. About 400 reports have been used. Many articles containing data primarily on hair sample preparation and chemical analytical methodology have not been cited.

All available critical data have been concisely presented in tabular form. Many reports do not cite the age, sex, number of subjects, and other critical data. All data have been cited as ppm, (or pCi/g) for data on radionuclides. The data on ranges are put in parentheses followed by the average and the standard error (SE) or standard deviation (SD), if these are available. Some references (particularly foreign) were available only from abstracts or reviews and the presentation of these data may not be complete. This is the first known comprehensive review for toxic trace elements in human hair and nails.

TABLE A-1. ANTIMONY IN HUMAN HAIR

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
United States Tennessee	33 adults and children	(0.5-4.0)1.5	Bate & Dyer (1965)
United States		6.5	Schroeder & Nason (1971)
United States	32 young males in Navy	(means) 0.107	Gordus et al.(1974)
" "	32 young males 5 mos. later	0.254	"
" "	32 young males 17 mos. later	0.166	"
" "	108 young males in Navy	(medians) 0.073	"
" "	70 young males 5 mos. later	0.19	"
" "	56 young males 17 mos. later	0.2	"
" "	14 females 1800-1900	0.5	"
" "	43 females 1900-1930	0.63	"
" "	24 young males in Navy	(0.03-1.5)	Gordus (1973)
" "	41 females age 18-22 U. Mich. students	(geom. means) 0.084	Gordus et al.(1975)
" "	27 females age 12-40 yrs. 1910-1935	0.507	"
" "	11 females age 12-40 yrs. 1890-1910	0.779	"
" "	10 females age 12-40 yrs. before 1890	0.476	"
Canada Yellowknife, NWT	12 residents in Yellowknife, 1.5-23 yrs.	(0.2-0.97)0.54	O'Toole et al.(1971)

(Continued)

TABLE A-1. ANTIMONY IN HUMAN HAIR (Continued)

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
Canada		(0.0-10.0)	Perkons & Jervis (1965)
"	76 rural residents of central Canada	(1.3-24.0)7.9 med.	Chattopadhyay & Jervis (1974)
Toronto	45 urban residents	(1.5-33.0)9.7 med.	"
Canada	121 urban near refineries	(1.8-47.0)14.6 med.	"
	Environmental location influences the Sb content of hair significantly		
Venezuela	11 Amazonian Indians	(<0.4-3.1)1.25 1.7 med.	Perkons (1977)
Poland	Conc. of Sb was similar from 1-66 cm. in 3 cm. sectional analyses of hair		Dybczynski & Boboli (1976)
Iraq	175 rural and urban residents	(<0.1-8.0)1.9	Al-Shahristani (1976)
Morocco	115 workers in antimony mines	"more than 1 g/kg of Sb was found in hair samples" = 1,000.0 ppm'.	Rodier & Souchere (1957)
Japan	43 rural residents	(0.009-4.3) 0.2±S.D. 0.66, 0.065 med., 0.077 geom. mean	Ohmori et al. (1975)
New Zealand Hasting	33 elementary school boys	(0.1-1.4)0.69	Bate & Dyer (1965)
Napier	33 elementary school boys	(0.0-4.4)0.36	"

TABLE A-2. ARSENIC IN HUMAN HAIR

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
United States		2.0	Schroeder & Nason (1971)
United States	Hair samples used to monitor As		Strain & Pories (1972)
	7 persons analyzed:		Schroeder & Balassa (1966)
	Age Hair color Sex		
	80 yrs. black male	1.1	"
	66 yrs. red male	0.72	"
	58 yrs. grey male	0.83	"
	35 yrs. brown female	0.21	"
	35 yrs. bleached black female	0.28	"
	20 yrs. brown female	0.49	"
	3 yrs. blonde female	0.12	"
United States	"Normal hair"	0.036-0.88	Vallee et al. (1960)
United States	Maximum level of "normal" hair	1.0	Rothman (1954)
United States	As is probably arsenite, bound in keratin		Schroeder & Balassa (1966)
United States Montana	4th grade school boys:		Hammer et al. (1972b)
E. Helena	16 boys, area heavily polluted from smelters	(<1.0-39.0)5.2±S.D. 6.0, Median 4.0	"
Helena	13 boys, some pollution from smelters	(<1.0-1.0)0.84±S.D. 0.33, Median 0.7	"
Bozeman	28 boys, little pollution	(<1.0-1.0)0.44±S.D. 0.27, Median 0.4	"
United States Washington Tacoma	13 children, 3-4 grade 300 yds. from Cu smelter	(20.0-100.0)60.0	Milham & Strong (1974)

(Continued)

TABLE A-2. ARSENIC IN HUMAN HAIR (Continued)

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
United States Washington Tacoma	7 children, 3-4 grade 8 mi. from Cu smelter	(0-5) 3.0	Milham & Strong (1974)
"	Hair of children nearer to the smelter were much higher (20X). This correlated with levels in urine		"
United States Chicago	Determined "normal" levels of As in hair		Camp & Gant (1949)
United States	Determined "normal" levels of As in hair of non-exposed persons		Boylen & Hardy (1967)
United States	Determined "normal" levels of As in hair		Shapiro (1967)
United States	33 young males in Navy	0.19	Gordus et al. (1974)
" "	33 young males 5 mos. later	0.13	"
" "	33 young males 17 mos. later	0.13	"
" "	131 young males in Navy	0.13 median	"
" "	70 young males 5 mos. later	0.17 median	"
" "	55 young males 17 mos. later	0.12 median	"
" "	14 females 1800-1899	5.2 median	"
" "	43 females 1900-1930	0.8 median	"

(Continued)

TABLE A-2. ARSENIC IN HUMAN HAIR (Continued)

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
United States Michigan	12 males age 18-22 washed hair 2X/mo.	0.21	Gordus et al. (1975)
" "	12 males, age 18-22 washed hair 20X/mo.	0.35	"
" "	41 females, age 18-22, students	0.04	"
United States	27 females, age 12-40, 1910-1935	1.2	"
" "	11 females, age 12-40 1890-1910	1.5	"
" "	10 females, age 12-40, before 1890	2.5	"
Canada	Various occupations, male	1.5-120.0	Herman (1954)
"	" " female	0.1-0.4	"
Canada Yellowknife	12 residents for 1.5-23 years	(1.04-25.3)13.5	O'Toole et al. (1971)
Canada		1.0-2.5	Perkons & Jervis (1965)
Canada	45 urban residents of Toronto	(0.4-2.1)0.75 med.	Chattopadhyay & Jervis (1974)
Canada	121 urban near refineries	(0.63-4.9) 1.9 med.	"
"	76 rural residents of central Canada	(0.45-1.7)0.68 med.	"

(Continued)

TABLE A-2. ARSENIC IN HUMAN HAIR (Continued)

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
Mexico Peubla	22 children, age 7-14 yrs. living near 43 wells with >0.01 ppm As in water and 9>0.05 ppm		Gonzales et al. (1972)
"	As poisoned sick children, 5 male, 3 female	>2.1	"
"	14 children, apparently well:		
	7 males	<2.1	"
	5 females	<2.1	"
	2 females	>2.1	"
"	Normal limits As 0.5-2.1 ppm in hair		"
Venezuela	11 Amazonian indians	(<0.2-1.15)0.5 0.65 med.	Perkons (1977)
Chile Antofagasta	130,000 inhabitants drank water with 0.8 ppm As for 12 yrs. Hair of 83% of over 1800 samples had abnormally high As; 30% of population had cutaneous lesions		Borgono & Greiber (1972)
"	of 204 persons, 168 or 82.6%	>1.0	"
"	of 204 persons, 36 or 17.4%	<1.0	"
"	Mean	9.2	"
"	5 persons, July '68	(0.56-1.4)1.05	"
"	3 persons, Nov. '68	(0.47-1.58)0.95	"
"	Water treatment started May 1970		

(Continued)

TABLE A-2. ARSENIC IN HUMAN HAIR (Continued)

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
Chile Antofagasta	3 persons, July '69	(0.0-0.22)0.14	Borgono & Greiber (1972)
"	6 persons, Jan. '71	(0.0-0.08)0.03	"
"	103 persons (1969)	4.2	"
"	10 normal skin	3.2	"
"	93 abnormal skin pigmentation	6.1	"
Iquique	(No arsenic in water, control, 1969)		
	26 persons, normal skin	0.08	"
"	0 persons, abnormal pigmentation		"
Chile Toconee	Water 0.6-0.8 ppm As	(0.0-83.4)10.2	"
Siloli	Trace As in water	(0.0-15.5)4.0	"
Antofagasta	35 mummies	0.8-38.3	"
Argentina	As affects sulfhydryl groups & goes in hair & nails		Astolfi (1971)
Argentina	"Normal" values given for hair		Guatelli (1961)
Great Britain	Chemical workers making sodium-arsenite (at three levels of exposure	108.0 85.0 64.0	Hill & Faning (1948)
" "	Unexposed controls	13.0	"

(Continued)

TABLE A-2. ARSENIC IN HUMAN HAIR (Continued)

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
Ireland	Rural area near zinc copper mine:		Corridan (1974)
"	21 children age 5-12 yrs.	(0.3-6.1)2.1 S.D.±1.34	"
"	Composite of 3 samples	2.25	"
"	Rural children, unexposed	(0.08-0.18)0.12	"
"	Children near mine had 17.5 X As than unexposed rural children		"
Scotland Glasgow	82 persons	(0.038-0.53)0.13 geom. mean	Dale et al. (1975)
"	Female laboratory technicians using detergent shampoo with 74 ppm As	42.0	Lenihan et al. (1958)
Scotland Glasgow	"Normal"	2.0	Polson & Tattersall (1969)
"	Suspect poisoning	>3.0	"
"	Chronic poisoning	12.0	"
"	Industrial occupational exposure (dust in air)	>300.00	Smith (1964)
Scotland	1,250 samples	(0.02-8.17)0.65 ±S.D. 0.698 median 0.46	Smith (1970)
"	Over 1,000 subjects	80% less than 1.0	Leniham & Smith (1959)
"	Arsenic content of male hair significantly higher than female		"

(Continued)

TABLE A-2. ARSENIC IN HUMAN HAIR (Continued)

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
Scotland	Male sheep dip worker with As poisoning: Wks. after admission in hospital		Leniham & Smith (1959)
	beard hair 0	3.12	
	" 1	1.79	
	" 3	0.84	
	" 4	0.94	
Switzerland		9.7	Billeter et al. (1923)
France	A 22-mo. girl ate As-contaning chalk. After 2 mo. treatment with BAL higher than normal levels of As were found in hair		Dequidt et al. (1972)
France	Napoleon's hair - 2 samples tested	10.3	Smith et al. (1962)
"	Napoleon's hair - intermittent accumulation in sections	3.27-3.75	Forshufvud et al. (1961)
Czechoslovakia	"Controls" - 10 yr. old normal boys		Bencko (1966)
"	10-yr. -old boys in As containing area around a thermal power plant emitting 1 ton As/day	3.5 x controls	"
Czechoslovakia	Hair levels showed correlation with environmental gradient of As from source		Bencko et al. (1971)

(Continued)

TABLE A-2. ARSENIC IN HUMAN HAIR (Continued)

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
Germany	Hair may have had some external contamination of As	(4.0-1,585.0)411.0	Schwarz (1932)
Iraq	175 rural and urban residents	(<0.08-1.4)0.4	Al-Shahristani (1976)
Sri Lanka	Residents of Sri Lanka	(0.01-0.35)0.15± S.D. 0.34	Dale et al. (1975)
Taiwan	83 cases carcinomas of nose (also high Ni)		Fresh et al. (1967)
"	Patients showed 87% higher As in hair than "normal"		"
Japan	8 As patients drank As contaminated powdered milk	(10.0-60.0)	Okamura et al. (1956)
"	"Normal" As in hair	(1.5-2.0)	"
"	7 - 2nd grade boys near smelter	(0.05-12.0)1.87 geom. mean	Suzuki et al. (1974)
"	Exposed were 6 x control	(0.07-0.5)0.3 geom. mean	"
"	41 rural residents	(0.01-0.58)0.13 ±S.D. 0.12 0.095 med., 0.083 geom. mean	Ohmori et al. (1975)
New Zealand Hastings	33 school boys	(0.4-7.9)2.4	Bate & Dyer (1965)
Napier	33 school boys	(0.7-5.3)1.8	"

(Continued)

TABLE A-2. ARSENIC IN HUMAN HAIR (Continued)

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
Country Unspecified	1,000 subjects	(0.03-74.0)0.81	Smith (1964)
"	1,000 subjects	Median 0.51, 95% <2.0 99% <4.5	"
"	As level over 3.0 is probably arsenic poisoning		"
	"Normal" values of As in hair	(0.25-1.0)	Kyle (1970)
"	Six patients with As poisoning	(17.6-85.0)48.8	"
"		(0.5-2.1)1.1	Smales & Pate (1952)
Country Unspecified	As appears in sweat soon after ingestion and sweat carries dissolved As along hair shafts and it binds with S in the hair		Lander et al. (1965)
"	Hair of workers in arsenic ore mines (without simultaneous increase in urine)	to 1,000.0	Van den Berg (1969)

Type of Locality	As exposure	No. 4th grade boys	Geom. Mean	Median	Arith. Mean	S.D.	
Copper smelting	highest	31	9.1	9.1	10.6	7.0	Hammer et al (1971)
Lead & Zn smelting	high	16	3.0	4.0	5.2	6.0	"

(Continued)

TABLE A-2. ARSENIC IN HUMAN HAIR (Continued)

Type of Locality	As exposure	No. 4th grade boys	Geom. Mean	Median	Arith. Mean	S.D.	
Lead & Zn mining & smelting	intermediate	32	1.2	1.1	1.7	1.48	Hammer et al (1971)
Govt. & commercial	intermediate	13	0.7	0.7	0.8	0.33	"
Education & farm trading	low	28	0.3	0.4	0.4	0.26	"
	120 hair As levels reflected environmental exposure gradient in 1969						"
	76 hair As levels in 1970 reflected environmental exposure gradient with a correlation r of 0.74 with a P value of <0.001						

TABLE A-3. ARSENIC IN HUMAN NAILS

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
United States		1.5-4.0	Vallee et al. (1960)
" "		0.087-0.63	"
	Found As in fingernails		Cooper & Langford (1972)
Mexico	43 wells had over 0.01 ppm As in water, and 9 over 0.05 ppm		Gonzales et al. (1972)
"	22 children age 7-14 yrs. lived near contaminated wells		"
"	8 As poisoned sick children:		
"	4 male	>3.5	"
"	3 female	>3.5	"
"	1 male	<3.5	"
"	14 apparently well:		
"	2 female	>3.5	"
"	5 male	<3.5	"
"	7 female	<3.5	"
"	Normal limits of As in nails	0.82-3.5	"
Scotland	124 samples	D (0.02-2.9)0.362 ±S.D. 0.313 median 0.3	Smith (1970)
Country Unspecified	Fingernails	0.82-3.5	Smales & Pate (1952)
"	Toenails	0.52-5.6	"

(Continued)

TABLE A-3. ARSENIC IN HUMAN NAILS (Continued)

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
Country Unspecified	Presence of white striae in fingernails is usually diagnostic of arsenical polyneuritis		Mees (1919)
"	Broad white band observed in heavy poisonings		"
Taiwan	87% of cancer patients showed higher As in fingernails than normal (also high Ni)		Fresh et al. (1967)
France	22 mo. girl ate As in chalk and had high As level in nails		Dequidt et al. (1972)
Country Unspecified	Six patients with As poisoning	(0.0-420.0) 102.8	Kyle (1970)
"	Cumulative arsenic poisoning resulting in death has been established by analysis of nail sections progressively nearer to the matrix		Shapiro (1967)
"		17.2	Billeter et al. (1923)

TABLE A-4. BORON IN HUMAN HAIR

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
United States	Age 15-70, hair colors dark brown, black, or gray	0.02-0.08	Goldblum et al. (1953)
New York	Boron in scalp hair did not display significant association with environmental gradients		Creason et al. (1975)
United States		7.0	Schroeder & Nason (1971)

TABLE A-5. CADMIUM IN HUMAN HAIR

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
United States	165 hair Cd levels reflected environmental exposure gradient in 1969		Hammer et al. (1971)
" "	114 hair Cd levels in 1970 reflected environmental exposure gradient with a correlation r of 0.28 with a P value of <.001		Hammer et al. (1972a)
" "	Hair Cd levels are not correlated with toxicity		"
United States	40 persons, atomic absorption spectrophotometry using method of additions	2.86±0.35	Sorenson et al. (1973b)
" "	40 persons, atomic absorption spectrophotometry using method of interpolation	2.6±0.02	"
" "	Cd hair levels are not related to toxicity		Fairhall (1957)
" "	Cd varied along length of hair indicating past Cd exposure	0-9cm,0,1-0.2 9-14 cm,0.2-0.43	Parker et al. (1973)
United States	12, various areas, age 12-60 yrs.	(0.6-6.9) 2.33	Hinners et al. (1974)
" "	86% Cd was extracted from hair by HNO_3		"
" "	Hair samples of Cd taken a year apart correlated well in the same individuals		Hammer et al. 1972a)

(Continued)

TABLE A-5. CADMIUM IN HUMAN HAIR (Continued)

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
New Hampshire Hanover	82 males	2.76±0.483	Schroeder & Nason (1969)
"	47 females	1.77±0.239	"
"	24 females, age 1-30 yrs	2.59±0.379	"
"	22 females, age 40-70 yrs.	0.92±0.153	"
"	12 males, 70-102	1.56±0.417	"
"	50 males, natural color	2.74±0.255	"
"	38 females, natural color	2.6±0.289	"
"	40 males, grey & white	2.21±0.439	"
"	15 females, grey & white	0.78±0.138	"
"	5 females, natural color, age 40-70	1.46±0.444	"
"	15 females, grey & white, age 40-70	0.78±0.138	"
"	7 males, blonde	2.83±0.529	"
"	25 males, brown	2.71±0.431	"
"	8 males, black	0.78±0.193	"
"	7 males, red	3.93±0.746	"
"	8 females, red	3.08±0.53	"
New Hampshire	In males there was less Cd in black than in other colors. Female grey hair had less Cd than in male grey hair		Schroeder & Nason (1969)

(Continued)

TABLE A-5. CADMIUM IN HUMAN HAIR (Continued)

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
New York	Environmental exposure gradients of Cd displayed no significant association of adult and child hair Cd levels. Scalp hair Cd levels for males and females were not significantly different		Creason et al. (1975)
New York	Human hair levels were highest in adults living closest to Cd usage areas (golf course). High Cd levels of hair were correlated only with elevated diastolic blood pressure:		Keil et al. (1975)
	23 persons age up to 12 yrs. ave. 9.7 yrs.	1.7±S.D.1.6	"
	16 persons age 13-21 yrs. ave. 15.3 yrs.	1.7±S.D.2.5	"
	7 persons age 22-35 yrs. ave. 30.0 yrs.	4.5±S.D.8.8	"
	86 persons age over 36 yrs. ave. 50.9 yrs.	3.8±S.D.7.5	"
New York Riverside	43 persons	0.915	Pinkerton et al. (1973)
Queens	31 persons	1.264	"
Bronx	28 persons	0.599	"
Michigan	12 males, age 18-22 yrs. washed hair 2 x/mo.	1.2	Gordus et al. (1975)
"	12 males, age 18-22 yrs. washed hair 20 x/mo.	1.4	"

(Continued)

TABLE A-5. CADMIUM IN HUMAN HAIR (Continued)

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
Ohio	Determined Cd levels in hair in relation to age and sex:		Petering et al. (1975)
"	95 white males, age 2-88 yrs.	2.2±0.2	"
"	" " " 2 yrs.	1.4	"
"	" " " 7 yrs.	2.0	"
"	" " " 20 yrs.	2.5	"
Ohio	white males, age 30 yrs.	1.8	Petering et al. (1973)
"	" " " 80 yrs.	1.8	"
"	83 white females, age 14-84 yrs.	2.43±0.26	"
"	" " 14 yrs.	1.2	"
"	" " 30 yrs.	1.5	"
"	" " 40 yrs.	2.5	"
"	" " 50 yrs.	2.1	"
"	" " 80 yrs.	1.6	"
Texas	Petrochemical Industry:		Eads & Lambdin (1973)
Port Arthur	26 males, age 9-60 yrs.	(0.1-9.3)2.2	"
" "	21 females, age 13-72 yrs.	(0.2-3.6)1.0	"
" "	Cd was fairly uniformly distributed in both male and female		"

(Continued)

TABLE A-5. CADMIUM IN HUMAN HAIR (Continued)

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
Montana			Hammer et al. (1972b)
E. Helena	4th grade school boys:		
	25 boys, heavily polluted from smelter complex	(<1.0-6.0)2.0±S.D. 1.54 Median 1.6	"
Helena	21 boys, some pollution from smelter	(<1.0-6.0)1.3±S.D. 1.3 Median 0.9	"
Bozeman	37 boys, little pollution	(<1.0-3.0)0.9±S.D. 0.58 Median 0.8	"
	The differences between the Cd content of the hair follows an environmental gradient		
Central Canada	76 rural residents	(0.25-2.7)1.2 med.	Chattopadhyay & Jervis (1974)
" "	45 urban, Toronto	(0.32-3.4)2.0 med.	"
" "	121 urban near refineries	(0.45-8.2)4.1 med.	"
Sweden	Cd^{109} adsorption occurred in human hair & the amount was related to hair acidity		Nishiyama & Nordberg (1972)
"	Cd workers had Cd in hair after detergent washing	>1000.0	"
Finland	Autopsy of 6 Finnish hair samples showed 33% positive (over 0.002% of ash)	1.36% of dry weight of ash	Forssen (1972)
Japan	36 females sampled from epidemic Cd district. 25 males sampled from epidemic itai-itai disease area, and 6 females sampled from safe districts.		Ishizaki et al. (1969)

(Continued)

TABLE A-5. CADMIUM IN HUMAN HAIR (Continued)

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
Japan	The hair of young females had highest Cd in non-epidemic districts. There was no remarkable difference between epidemic and non-epidemic districts. Cd in hair was not very effective for clinical diagnosis.		Ishizaki et al. (1969)
Country Unspecified	"Normal" range	0.2-2.0	Friberg et al. (1971)
United States			

Type of Locality	Cd exposure	No. 4th grade boys	Geom. Mean	Median	Arith. Mean	S.D.	
Lead & zinc mining & smelting	high	45	2.1	2.1	3.5	4.94	Hammer et al. (1971)
Lead & zinc smelting	high	25	1.5	1.6	2.0	1.54	"
Copper smelting	low	37	1.0	1.0	1.3	0.99	"
Govt. & commercial	low	21	1.0	0.9	1.3	1.30	"
Education & farm trading	low	37	0.7	0.8	0.9	0.58	"
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TABLE A-6. CHROMIUM IN HUMAN HAIR

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
United States	New born baby hair	0.974	Hambidge (1971)
" "	Maternal hair	0.382	"
" "	Premature infant hair has low Cr. The Cr level in hair of fetus increases with age.		Hambidge & Baum (1972)
United States	Cr in hair of parous women	(0.04-1.14)	Hambidge & Rodgerson (1969)
" "	Nulliparous women	(0.2-2.81)	"
" "	Repeated pregnancies result in significant decrease of hair Cr of mother		"
" "	25, age 0-7 days	0.91±S.E. 0.139	"
" "	6, age 3-6 months	1.493±S.E. 0.386	"
" "	8, age 8 months	0.85±S.E. 0.106	"
" "	11, age 10-12 months	0.631±S.E. 0.062	"
" "	23, age 1-2 years	0.525±S.E. 0.059	"
" "	20, age 2-3 years	0.412±S.E. 0.047	"
" "	Cr in 3-8 mo. infants significantly higher than in 2-3 yr. old children		"
United States	Cr of hair is not related to external environment Cr, but to Cr nutritional status of individual		Hambidge et al. (1972b)
New York	Cr environmental exposure gradients were reflected in children's hair only		Creason et al. (1975)

(Continued)

TABLE A-6. CHROMIUM IN HUMAN HAIR (Continued)

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
United States	63 males	0.69±0.063	Schroeder & Nason (1971)
" "	5 females	0.96±0.049	"
" "	48 males, natural hair color	0.69±0.062	"
" "	14 males, grey & white	0.73±0.148	"
" "	5 females, grey & white	0.96±0.049	"
" "	9 males, red hair	0.39±0.048	"
" "	68 persons	(0.0-2.2)	"
" "	Cr in hair relatively constant with age		Schroeder & Nason (1969)
United States	32 males, age 18-22 in Navy	Means 1.4	Gordus et al. (1974)
" "	32 males, age 18-22 5 mos. later	1.6	"
" "	32 males, age 18-22 17 mos. later	1.5	"
" "	122 males, age 18-22 in Navy	Medians 1.3	"
" "	70 males, age 18-22 5 mos. later	1.6	"
" "	57 males, age 18-22 17 mos. later	1.7	"
" "	14 females, 1800-1899	2.6	"
" "	43 females, 1900-1930	3.2	"

(Continued)

TABLE A-6. CHROMIUM IN HUMAN HAIR (Continued)

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
United States	41 females, age 18-22 U. Mich. 1972	Geom. means 1.4	Gordus et al. (1975)
" "	27 females, age 12-40 yrs. 1910-1935	3.9	"
" "	11 females, age 12-40 yrs. 1890-1910	3.8	"
" "	10 females, age 12-40 yrs. before 1890	2.4	"
Canada Yellowknife	12 residents, 1.5-23 yrs.	(0.0-6.43)2.46	O'Toole et al. (1971)
Canada		(2.0-5.5)	Perkons & Jervis (1965)
Country Unspecified		(2.0-4.0)	Quittner et al. (1970)
Venezuela	11 Amazonian indians	(7.4-8.9)8.3 Median 8.3	Perkons (1977)
Japan	4 rural residents	(0.1-14.0)1.4±S.D. 3.0 Median 0.6 Geom. mean 0.6	Ohmori et al (1975)
Iraq	175 rural and urban	<0.8-20.0)5.7	Al-Shahristani (1976)

TABLE A-7. CHROMIUM IN HUMAN NAILS

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
Country Unspecified	Cr is lower in fingernails of atherosclerotic persons		Masironi (1974)
"	Periungual sites are sites of Cr ulcers		Nat. Acad. Sci. (1974)

TABLE A-8. COBALT IN HUMAN HAIR

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
United States	19 males	0.17±0.026	Schroeder & Nason (1971)
" "	11 females	0.28±0.043	"
" "	12 males, age 40-70 yrs.	0.13±0.039	"
" "	1 male, 102 yrs.	<0.1	"
" "	31 persons	(0.0-0.5)	"
" "	8 males & 1 female, age 5-19 yrs.	0.54	Schroeder et al. (1967)
" "	1 female, red hair, age 17 yrs.	0.71	"
" "	1 female, black hair, age 18 yrs.	0.43	"
" "	1 male, white hair age 102 yrs.	3.11	"
" "	Estimated daily excretion in hair	2.4 μg/day	Howells (1967)
United States	32 males, age 18-22 yrs. in Navy	Means 0.041	Gordus et al. (1974)
" "	32 males, age 18-22 yrs. 5 mos. later	0.028	"
" "	32 males age 18-22 yrs. 17 mos. later	0.03	"
	132 males age 18-22 yrs. in Navy	Medians 0.045	"
" "	70 males age 18-22 yrs. 5 mos. later	0.036	"
" "	57 males age 18-22 yrs. 17 mos. later	0.03	"

(Continued)

TABLE A-8. COBALT IN HUMAN HAIR (Continued)

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
United States	14 females, 1800-1899	0.13	Gordus et al. (1974)
" "	53 females, 1900-1930	0.053	"
Michigan	12 males, washed hair 2x/mo.	0.19	Gordus et al. (1975)
"	12 males, washed hair 20x/mo.	0.13	"
"	41 females, age 18-22 yrs., 1972	0.106	"
United States	27 females, age 12-40 yrs., 1910-1935	0.054	"
" "	11 females, age 12-40 yrs., 1890-1910	0.069	"
" "	10 females, age 12-40 yrs., before 1890	0.125	"
Canada Yellowknife	12 residents for 1.5-23 yrs.	(0.026-0.47)0.25	O'Toole et al. (1971)
Canada		(0.0-1.0)	Perkons & Jarvis (1965)
Canada	76 rural & urban residents of Central Canada	(0.12-1.8)0.41 med.	Chattopadhyay & Jervis (1974)
"	43 urban residents of Toronto	(0.15-2.6)0.48 med.	"
"	121 urban near refineries	(0.1-3.3)0.5 med.	"
Venezuela	11 Amazonian indians	(0.53-2.83)1.7 median 1.52	Perkons (1977)
Italy	8 persons in Amiata Mt.	0.11	Clemente (1977)
Iraq	175 rural and urban residents	(<0.1-1.2)0.4	Al-Shahristani (1976)

TABLE A-9. COPPER IN HUMAN HAIR

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
United States New Hampshire	79 males	16.1±1.19	Schroeder & Nason (1969)
" "	47 females	55.6±10.27	"
" "	24 females, age 1-30 yrs.	86.2±16.67	"
" "	22 females, age 40-70 yrs.	16.6±1.58	"
" "	12 males, age 70-102 yrs.	12.7±1.8	"
" "	1 male, age 62 (washed hair in high Cu-containing water)	(425.0-486.0)	"
" "	50 males, natural color	18.4±1.94	"
" "	38 females, natural color	66.7±12.06	"
" "	38 males grey & white	14.2±1.1	"
" "	16 females, grey & white	14.6±1.6	"
" "	5 females, natural color	19.4±2.13	"
" "	15 females, grey & white	14.7±1.7	"
" "	7 males, red color	22.4±7.05	"
" "	7 females, red color	24.1±4.25	"
New York Riverhead	43 persons	13.88	Pinkerton et al. (1973)
Queens	31 persons	17.94	"
Bronx	28 persons	11.29	"
New York	Concentrations of Cu in scalp hair was not associated with environmental exposure gradients		Creason et al. (1975)
" "	Scalp hair of females was higher than males		"
Virginia	short samples near nape of neck	(10.0-24.0)13.5	Harrison et al. (1969)

(Continued)

TABLE A-9. COPPER IN HUMAN HAIR (Continued)

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
Michigan	12 males washed hair 2 x/mo.	24.0	Gordus et al. (1975)
"	12 males washed hair 20 x/mo.	32.0	"
"	41 females, age 18-22 yrs. 1972	21.0	"
United States	27 females, age 12-40 yrs., 1910-1935	11.0	"
" "	11 females, age 12-40 yrs., 1890-1910	12.0	"
" "	10 females, age 12-40 yrs., before 1890	13.0	"
Michigan	18 persons, age 15-70 yrs., hair color dark brown, black, or grey	31.2-128.0	Goldblum et al. (1953)
Tennessee	33 adults and children	(7.8-234.0)34.1	Bate & Dyer (1965)
Ohio	211 persons, age 1-80 yrs:		Petering et al. (1971)
"	male age 2 yrs.	13.0	"
"	male age 12 yrs.	60.0	"
"	male age 40 yrs.	18.0	"
"	male age 80 yrs.	9.0-10.0	"
"	female age 15 yrs.	19.0	"
"	female age 20 yrs.	18.0	"
"	female age 30 yrs.	30.0	"
"	female age 50 yrs.	20.0	"
"	female age 80 yrs.	25.0	"
Ohio	95 males, age 2-88 yrs.	34.7±6.7	Petering et al. (1973)
"	83 females, age 14-84 yrs.	29.6±2.8	"

(Continued)

TABLE A-9. COPPER IN HUMAN HAIR (Continued)

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
Ohio Cincinnati	50 females (inner city, low socio-economic status, non-lactating)	17.9±S.D. 11.0	Baumslag & Petering (1976)
Ohio		(95% conf. int.)	Baumslag et al. (1974)
"	50 scalp, female	(17.3-18.4)17.9	"
"	51 pubic, female	(12.8-13.2)13.0	"
"	37 scalp, newborn	(10.5-11.3)10.9	"
"	Maternal age 15-19 yrs. infant hair	(8.7-16.6)12.0	"
"	Maternal age 20-24 yrs. infant hair	(8.0-15.0)11.0	"
"	Maternal age 25-29 yrs. infant hair	(3.5-21.4)8.7	"
"	Maternal age 30-39 yrs. infant hair	(2.1-42.3)9.3	"
"	white newborn	18.4	"
"	black newborn	10.5	"
"	Parity 1, black newborn	7.8	"
"	Parity 2-3, black newborn	9.8	"
"	Parity 4 or more, black newborn	15.1	"
Texas	20 males, age 9-60 yrs.	(10.7-41.6)22.6	Eads & Lambdin (1973)
"	14 females, age 13-72 yrs.	(11.4-61.4)23.0	"

(Continued)

TABLE A-9. COPPER IN HUMAN HAIR (Continued)

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
United States various areas	12 persons, age 12-60 yrs.	(9.4-31.0)16.7	Hinners et al. (1974)
" "	33% Cu was extracted from hair by HNO_3		"
United States	33 males, age 18-22 yrs. in Navy	medians 8.0-30.0	Gordus (1973)
" "	42 males, age 18-22 yrs. in Navy	19.0	Gordus et al. (1974)
" "	42 males, age 18-22 yrs. 5 mos. later	14.0	"
" "	42 males, age 18-22 yrs. 17 mos. later	15.0	"
" "	120 males, age 18-22 yrs.	means 17.0	"
" "	78 males, age 18-22 yrs.	15.0	"
" "	64 males, age 18-22 yrs.	14.0	"
" "	52 females, young	14.0	"
" "	12 females, 1800-1899	18.0	"
" "	28 females, 1900-1930	12.0	"
United States	40 persons, method of additions	70.0±9.31	Sorenson et al. (1973b)
" "	40 persons, method of interpolation	71.25±1.51	"
" "	single female, 30 cm. of hair - proximal	15.0	Renshaw et al. (1973)
" "	single female, 30 cm. of hair - distal ends	63.0	"
" "	In 17 females and 40 males Cu levels increased from root to tip with greater variation in distal end		

(Continued)

TABLE A-9. COPPER IN HUMAN HAIR (Continued)

United States Type of City	Cu exposure	No. 4th grade boys	Geom. Mean	Median	Arth. Mean	S.D.	Hammer et al. (1971)
Lead & zinc mining & smelting	intermediate	45	17.1	13.0	25.7	28.1	"
Copper smelting	intermediate	37	13.9	12.0	15.3	7.5	"
Lead & Zinc smelting	low	25	10.4	11.0	11.8	3.0	"
Govt. & commercial	low	21	11.5	11.0	12.6	6.0	"
Education & farm trading	low	37	14.4	11.0	22.5	34.7	"
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United States	Hair Cu levels did not follow the estimated exposure gradient, but the distributions were positively skewed. Since the Cu exposure gradient was only low to intermediate, this relative homogeneity was not unexpected.		Hammer et al. (1971)
United States	In the following year, 115 boys in the 4th grade were re-tested with the same results that Cu hair levels did not reflect environmental exposure gradients.		Hammer et al. (1972a)
	Menkes' kinky hair syndrome is associated with low Cu in hair.		Singh & Bresman (1973)
Canada	135 vegetable producers	Ave. 16.0	Hutchinson et al. (1974)
"	75 vegetable producers, male	15.0	"
"	60 vegetable producers, female	16.6	"
"	18 packers, male	11.8	"

(Continued)

TABLE A-9. COPPER IN HUMAN HAIR (Continued)

Canada	60 packers, female	16.6	Hutchinson et al.
"	57 growers, male	16.6	"
"	Males vs. females	X^2=6.96 not signif.	"
"	Packers vs. growers (Male)	X^2=11.43 P=0.01	"
"	Males vs. females (packers)	X^2=13.37 P=0.001	"
"	<40 yrs. vs. >40 yrs.	X^2=2.72 not signif.	"
"	40 years intensive cultivation resulted in marked accumulation of Cu in cultivated soils		"
Venezuela	11 Amazonian indians	(2.5-102.0)18.2 med. 8.2	Perkons (1977)
Scotland	29 samples	(7.64-54.5)23.1±S.D. 11.7 median 19.1	Smith (1970)
Glasgow	29 "normal"	(7.64-54.5)23.0	Smith (1967)
"	29 persons	(7.6-55.0)20.6 geom. mean	Dale et al. (1975)
Ireland	Rural area near zinc copper mine:		Corridan (1974)
	18 males age 5-12 yrs. 3 females age 5-12 yrs.	(12.0-46.1)22.5	"
Ireland Cork City	20 children, 18 males & 2 females	(6.5-14.9)10.85	Corridan (1974)
German Democratic Republic	25 females, age 1-63 yrs.	40.8±S.D. 15.2 36.6 med.	Weisner et al. (1974)
Germany	22 males + 22 females Cu was slightly higher in black than brown, blonde, grey, or white hair		Anke & Schneider (1962)

(Continued)

TABLE A-9. COPPER IN HUMAN HAIR (Continued)

Iran	Hair Cu content varied with rural or urban areas		Reinhold et al. (1966)
Africa Botswana, Kalihari Desert	Kung Bushmen, 12 young women	(5.0-32.0)12.0± S.D. 10.0	Baumslag & Petering (1976)
"	11 lactating women	(2.0-14.0)8.0± S.D. 4.5	"
"	15 postmenopausal women	(1.0-37.0)12.0± S.D. 14.0	"
"	8 men	(9.0-19.0)11.0± S.D. 3.0	"
Republic of South Africa Johannesburg	Bantu 37 lactating women	9.9±S.D. 4.5	"
Japan	61 rural residents	(1.8-69.0)11.0± S.D. 11.0 10.0 med. 9.6 geom. mean.	Ohmori et al. (1975)
New Zeland	33 boys, elementary school:		Bate & Dyer (1965)
Hastings	" " " "	(7.0-93.0)30.0	"
Napier	" " " "	(8.0-150.0)15.5	"
	" " " "	(20.0-170.0)38.0	Backer (1969)
	Determined Cu in human hair using detergent and dry ashing		Briggs et al. (1972)
Country Unspecified		(0.1-1.0)	Quittner et al. (1970)

TABLE A-10. COPPER IN HUMAN NAILS

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
Scotland	33 samples	(3.18-58.2)18.1 ±S.D. 12.1 median 14.9	Smith (1970)
Country Unspecified	10 males, age 1-78 19 samples	(28.0-53.0)44.0	Harrison & Tyree (1971)
"	7 females, age 1-78 63 samples	(44.0-102.0)62.0	"
"	17 persons, age 1-78 82 samples total	(28.0-102.0)54.0	"
"	9 males	(9.4.81.0)	Goldblum et al. (1953)
"	13 adults	(29.3-74.0)51.1	Kanabrocki et al. (1968)
"	6 children	(42.1-131.1)86.4	"
"	6 males	(8.1-18.9)14.8	Martin (1964)
"	7 females	(6.8-15.3)10.6)	"
"	3 persons	0	Petrushkov et al. (1969)
"	Used atomic absorption analysis of Cu in nails		Barnett & Kahn (1972)
"	Cu content of nails was determined in normals and those with Wilson's disease		Martin (1964)
New Guinea	50 fathers, age 46±8 yrs. toenails	4.3±S.D.2.8 median 3.9 geom. mean 3.4	Masironi et al. (1976)
" "	50 mothers, age 41±8 yrs. toenails	4.2±S.D. 3.4 median 3.8 geom. mean 2.7	"

(Continued)

TABLE A-10. COPPER IN HUMAN NAILS (Continued)

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
New Guinea	34 male teenagers, age 15±2 yrs., toenails	4.5±S.D. 2.9 median 4.7 geom. mean 3.6	Masironi et al. (1976)
" "	23 female teenagers, age 15, toenails	3.8±S.D. 3.7 median 3.4 geom. mean 2.2	"
	differences not significant		

TABLE A-11. LEAD IN HUMAN HAIR

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
United States New Hampshire	78 males	17.8±S.E. 2.17	Schroeder & Nason (1969)
" "	47 females	19.0±S.E. 2.95	"
" "	24 females, age 1-30 yrs.	24.5±S.E. 4.9	"
" "	22 females, age 40-70 yrs.	8.4±S.E. 1.16	"
" "	12 males, age 70-102 yrs.	13.9±S.E. 6.44	"
" "	47 males, natural color	16.3±S.E. 2.03	"
" "	38 females, natural color	24.7±S.E. 3.24	"
" "	39 males, grey & white	18.7±S.E. 3.77	"
" "	16 females, grey & white	5.94±S.E. 0.873	"
" "	5 females, age 40-70, natural color	15.4±S.E. 1.93	"
" "	15 females, age 40-70, grey & white	5.8±S.E. 0.92	"
" "	7 males, blonde	14.0±S.E. 3.01	"
" "	24 males, brown	18.4±S.E. 2.86	"
" "	7 males, black	7.86±S.E. 2.025	"
" "	5 males, red	7.0±S.E. 1.625	"
" "	8 females, red	19.3±S.E. 1.93	"
" "	141 persons	(0.0-95.0)	"
" "	26 children to 8 yrs. (normal)	(3.0-85.0)	"
" "	13 boys to 8 yrs.	23.6	"

(Continued)

TABLE A-11. LEAD IN HUMAN HAIR (Continued)

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
United States New Hampshire	13 girls to 8 yrs.	39.8	Schroeder & Nason (1969)
Boston	265 policemen, 0-1.5 cm. from scalp	ave. 17.6	Speizer et al. (1973)
"	265 policemen, 0-1.5 cm. from scalp	Seven over 60 ppm, with range (61.0-1,139.0)	"
"	256 policemen, 1.5-3.5 cm. from scalp	ave. 28.8	"
"	256 policemen, 1.5-3.5 cm. from scalp	Fourteen over 60 ppm. with range (61.0-2,080.0)	"
"	69 policemen, inside jobs	118.6	"
"	88 policemen, in cruisers	118.1	"
"	8 policemen, part in cruisers and part in traffic	131.9	"
"	79 policemen, on foot in traffic	147.9	"
"	20 policemen, in traffic on motorcycle	183.3	"
"	9 policemen, age 20-29	97.7	"
"	57 policemen, age 30-39	148.4	"
"	112 policemen, age 40-49	125.9	"
"	72 policemen, age 50-59	131.2	"
"	14 policemen, age 60-69	132.4	"
"	264 policemen, all ages and duties	132.5	"
"	Head hair levels high in 14 of 267 men, or 5.2%		"

(Continued)

TABLE A-11. LEAD IN HUMAN HAIR (Continued)

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
Boston	Of 705 children tested, 98 had high Pb levels in hair and these averaged lower mental ability		Pueschel et al. (1972)
"	41 normal unexposed children under age 8 yrs.	(2.0-95.0)±24.0	Kopito et al. (1967)
"	High level of Pb in hair occurred in children with chronic Pb poisoning	ave. 282.0	"
"	Lead intoxication in children	80.0	Kopito et al. (1969)
"	20 children, acute and chronic poisoning	(70.0-975.0)276.0	"
New York Riverhead	43 persons	9.904	Pinkerton et al. (1973)
Queens	31 persons	14.784	"
Bronx	28 persons	12.046	"
New York	Scalp hair Pb levels of adults and children and were significantly associated with environmental exposure gradients		Creason et al. (1975)
"	Adult male hair had higher values than female		"
Unitd States	36, under 16 yrs. 1871-1923	164.24±S.D. 20.7	Weiss et al. (1972)
" "	20, over 16 yrs. 1871-1923	93.36±S.D. 16.3	"
" "	119, under 16 yrs., 1971	16.23±S.D. 0.97	"
" "	28, over 16 yrs., 1971	6.55±S.D. 1.17	"
Pennsylvania	16, under 16 yrs. Philadelphia, Chestnut Hill	16.49±S.D. 2.9	"

(Continued)

TABLE A-11. LEAD IN HUMAN HAIR (Continued)

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
Pennsylvania	16, under 16 yrs. Philadelphia, Kensington	19.44±S.D. 2.8	Weiss et al. (1972)
"	16, under 16 yrs. Philadelphia, Germantown	16.74±S.D. 2.7	"
"	16, under 16 yrs. Philadelphia, Lawdale	13.96±S.D. 2.2	"
"	16, under 16 yrs., Newtown	11.08±S.D. 2.2	"
Michigan	39, under 16 yrs. W. upper peninsula	17.63±S.D. 1.7	"
	Pb decrease in hair in last 100 years despite increase of Pb in atmosphere		
Ohio	50 females, scalp	(95% conf. int.) (30.0-33.0)31.5	Baumslag et al. (1974)
"	51 females, public	(16.0-17.2)16.6	"
"	43 newborns, scalp	(13.1-14.7)13.9	"
"	Hair of newborn is higher than older children and many adult groups. Shows that lead is transferred from mother to fetus		"
"	Female, black, scalp hair	means, 49.3	"
"	Female, black, public hair	21.8	"
"	Female, white, scalp hair	15.5	"
"	Female, white, pubic hair	9.1	"
Ohio	95 males, white, age 2-88 yrs.	18.3±1.8	Petering et al. (1973)
"	males, white, age 2 yrs.	25.0	"
"	males, white, age 20 yrs.	14.0	"

(Continued)

TABLE A-11. LEAD IN HUMAN HAIR (Continued)

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
Ohio	males, white, age 85 yrs.	10.0	Petering et al. (1973)
"	83 females, white, age 14-84 yrs.	24.4±2.7	"
"	females, white, age 14 yrs.	4.0	"
"	females, white, age 35 yrs.	40.0	"
"	females, white, age 84 yrs.	2.0	"
Michigan	12 males, washed hair 2 X/mo.	3.1	Gordus et al. (1975)
"	12 males, washed hair 20 X/mo.	7.7	"
Tennessee	18 persons, age 10-49 yrs. EDTA washed	(2.3-38.3)16.8±2.0	Clark & Wilson (1974)
"	18 persons, age 10-49 yrs. ether washed	(2.6-40.3)19.1±4.3	"
Montana East Helena	25 boys, 4th grade, heavily polluted area industrial smelting	(0-199.0)44.3± S.D. 49.3 Median 20.0	Hammer et al. (1972b)
Helena	21 boys, 4th grade light pollution	(0-74.9)12.1± S.D. 11.4 Median 7.9	"
Bozeman	38 boys, 4th grade little pollution	(0-38.0)7.6± S.D. 5.0 Median 6.5	"
Texas Port Arthur	(Petrochemical industry) 26 males, age 9-60 yrs.	(10.6-191.0)26.7	Eads & Lambdin (1973)
" "	21 females, age 13-72 yrs.	(7.6-61.0)24.1	"

(Continued)

TABLE A-11. LEAD IN HUMAN HAIR (Continued)

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
California	(No occupational exposure)		Rabinowitz et al. (1976)
	male, age 53 yrs., 5-day beard	15.1	
"	male, age 49 yrs., 5-day beard	13.2	"
"	male, age 25 yrs., 5-day beard	16.0	"
"	Each male then received 100 μg/day of Pb^{204} stable non-radioactive Pb for 100 days. Peak level in beard occurred at 125 days or about 35 days following peak level in blood. Blood level rose rapidly but had declined rapidly when Pb in beard peaked.		"
United States	18, age 15-75, dark hair white, male, "normal" exposure	0.4-1.0	Goldblum et al. (1953)
" "	150 accidental deaths 15 g hair ave	(0.05-1.5)0.75 mg of Pb	Schroeder & Tipton (1968)
United States Various areas	12 persons, age 12-60 yrs.	(2.0-141.0)34.3	Hinners et al. (1974)
United States	"normal"	1.0-3.0	Dick & Skogerboe (1973)
" "	Severe poisoning	>5.0	"
" "	20 males, age 18-22 yrs. in Navy	4.1	Gordus et al. (1974)
" "	3 females, 1800-1899	1,250.0	"
" "	13 females, 1900-1930	106.0	"

(Continued)

TABLE A-11. LEAD IN HUMAN HAIR (Continued)

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
United States	25, hair cosmetics were tested and showed no increased head hair Pb levels		Speizer et al. (1973)
" "	40 persons (method of additions)	39.0±0.02	Sorenson et al. (1973a)
" "	40 persons (method of interpolation)	42.26±4.32	"
Canada	76 rural	(0.5-25.0)9.1 med.	Chattopadhyay & Jervis (1974)
"	45 urban, Toronto	(0.5-35.0)15.3 med.	"
"	121 urban near refineries	(10.0-350.0)45.3 med.	"
Canada Ottawa	Blood levels and head hair examined for Pb; levels showed no correlation with high Pb levels in water from electric kettles.		Wigle (1975)
British Columbia	100 smelter workers and families with 3 levels of exposure of Pb related to husbands' exposure. Head hair of persons from Trail and Nelson B.C. (control city) were compared.		Neri et al. (1975)
Ontario	Hair Pb levels were normal, but there were differences between vegetable growers & packers between males & females & between age groups.		Hutchinson et al. (1974)
Panama	For all 242 females the arith. mean was 34.6 geom. mean 18.6±S.D. 0.3		
"	Lead content of hair was correlated with place of residence, and the differences between sexes was highly significant with females having high Pb levels. The highest Pb levels were in Panama City with higher exposure. The gradient falls with distance from Panama City and Canal Zone to rural areas and is correlated with lower Pb in hair		"

(Continued)

TABLE A-11. LEAD IN HUMAN HAIR (Continued)

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
Great Britian London	^{210}Pb	0.034 pCi g	Jaworowski (1964)
"	32 lead workers	(24.0-1,880.0)51.7	Barry (1972)
Great Britian	8 children non-occupationally exposed	ave. 20.0	Barry & Mossman (1970)
Ireland	Rural area near zinc copper mine:		Corridan (1974)
"	21 children aged 5-12 years 18 males and 3 female	(0.4-12.2)3.1	"
"	urban children	(2.04-22.8)5.5	"
France Paris	52 yr. old man, Pb poisoning from water 0.9 mg. Pb/1	14.0	Worms et al. (1957)
France	2 deaths from Pb pipes with drinking water with 2.3 mg. Pb/1	94.7-124.0	Fourcade & Caron (1954)
Fed. Rep. Germany	18 persons, lived near lead processing plant	(9.0-95.0)39.0	Aurand & Sonneborn (1973)
"	53 "control persons," city dwellers	(0.5-59.0)12.5	"
"	Only 5 city dwellers in range of mean or above those near lead plant		"
Germany	"Normal," not working with lead products	17.0	Kraut & Weber (1944)
"	Adult males	14.7	"
"	Adult females	19.2	"
"	Sexual difference is highly significant	(t= 3.38, P=<0.001)	"

(Continued)

TABLE A-11. LEAD IN HUMAN HAIR (Continued)

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
Italy	4 mo. old infant had lead poisoning due to mother using lead nipple shields	12.5	Portigliatti-Barbos (1961)
Poland Warsaw	9 subjects, stable Pb	10.0	Jaworowski (1964)
	9 subjects, ^{210}Pb	0.034 pCi/g	"
Poland	57 uranium miners, ^{210}Pb	(0.34-3.72)1.42± 0.93 pCi/g	"
"	This is 50 x higher ^{210}Pb than unexposed		"
"	Miners working >10 yrs. ^{210}Pb was 2.5 x higher	1.83±0.96pCi/g	"
"	than miners <10 yrs.	0.73±0.33 pCi/g	"
"	There was 30% more ^{210}Pb in hair than in ribs of 2 U miners		Jaworowski (1965a)
"	21 females	(4.85-20.7)8.9	Jaworowski (1965b)
Bulgaria	"Normal" healthy people	7.66-10.13	Ivanov et al. (1962)
"	37 people with endemic nephritis	3.8-12.76	"
"	There was a higher Pb level in sick women		"
Yugoslavia	Normal scalp hair	0.2-0.6	Danilovic (1958)
"	Fatal case, eating Pb contaminated flour:		
	scalp hair	4.0	"
"	axillary hair	10.0	"

(Continued)

TABLE A-11. LEAD IN HUMAN HAIR (Continued)

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
United Arab Republic	67 workers exposed to Pb had high Pb in hair correlated with bio-chemical and clinical findings		El Dakhaklany & El Sadik (1972)
"	Excessive head hair level	30.0	"
India	Bengali women using red lead cometics had high concentrations of Pb in hair		Bagchi et al. (1940)
Japan	112 Pb exposed workers, dangerous exposure	>110.0	Suzuki et al. (1958)
"	" occupational normal	30.0-110.0	"
"	22 control non-occupational "normal" Pb exposure	<30.0	"
"	With increased Pb absorption, Pb content increased and elongation and strength of hair decreased		"
"	Pb content of hair indicates amount of exposure:		Nishiyama et al. (1957)
	negligible	<30	"
	moderate	30-110	"
	serious	>110	"
"	30 lead workers + 14 miners, hair was less strong than normal		Suzuki & Matsuka (1957)
"	112 Pb exposed workers:		Nishiyama et al. (1957)
	workers in storage battery plants	(37.5-550.0)217.3	"
"	rayon manufacturer	(46.7-616.8)168.1	"

(Continued)

TABLE A-11. LEAD IN HUMAN HAIR (Continued)

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
Japan	measuring instrument manufacture	11.3	Nishiyama et al. (1957)
"	automobile painting	6.1	"
"	bobbin painting	22.5	"
"	newspapr printing, male	30.9	"
"	" " female	93.3	"
"	Pb exposed workers in small printing offices		"
	male	106.4	
	female	116.3	
"	Pb of hair indicates degree of exposure to Pb		
"	male printers	(3.9-196.1)75.9	"
"	female printers	(13.4-215.3)115.4	"
	rayon manufacture	(13.9-616.8)163.3	"
"	Male "normals"	9.9	Suzuki et al. (1958)
"	Female "normals"	14.6	"
Country Unspecified	Female subject had higher Pb levels than males and Pb content of hair increased with age		Shabel'nik (1968)
Country Unspecified		35.0	Spector (1956)

(Continued)

TABLE A-11. LEAD IN HUMAN HAIR (Continued)

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
New Zeland	250 subjects	(2.0-360.0)12.8 Geom. mean 95% conf. limits 11.4-14.4 of geom. mean. Arith. mean 21.8	Reeves et al. (1975)
" "	133 males	(2.1-360.0)13.6	"
" "	117 females	(2.0-145.0)12.0	"
" "	28, age 1-10 yrs.	(2.5-68.5)13.0	"
" "	83, age 1-21 yrs.	(2.0-219.0)13.3	"
" "	87, age 22-42 yrs.	(2.3-283.0)12.4	"
" "	80,age 43-87 yrs.	(2.1-360.0)12.7	"
" "	36 males, age 1-21 yrs.	(2.5-219.0)15.8	"
" "	47 females, age 1-21 yrs.	(2.0-99.5)11.8	"
" "	51 males, age 22-42 yrs.	(2.3-283.0)13.5	"
" "	36 females, age 22-42 yrs.	(3.3-86.6)11.0	"
" "	46 males, age 43-87 yrs.	(2.1-360.0)12.3	"
" "	34 females, age 43-87 yrs.	(3.1-145.0)13.4	"
" "	28 printers, metal workers	(3.4-360.0)32.8	"
" "	44 office workers, student	(2.5-82.8)10.4	"
" "	61 farmers, salesmen, etc.	(2.1-121.0)11.1	"
" "	There is no significant difference between male and female, between age groups, at 90% conf. level. Occupational groups show very significant higher level (99.9% conf.) of printers, metalworkers, mechanics, and machinists, compared with office workers, farmers, and other occupations.		

(Continued)

TABLE A-11. LEAD IN HUMAN HAIR (Continued)

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
New Zealand	4 males used hair preparation containing 1.2% Pb acetate. These were removed from study.	(1,050.0-2,410.0)1,725.3	Reeves et al. (1975)

United States Locality	Exposure	No. 4th grade boys	ppm in hair				
			Geom. Mean	Median	Arith. Mean	± S.D.	
Lead & zinc mining & smelting	highest	45	57.7	52.0	107.1	138.8	Hammer et al. (1971)
Lead & zinc smelting	high	25	22.3	20.0	44.3	49.3	"
Copper smelting	low	37	10.5	13.0	14.3	14.1	"
Government & commercial	low	21	8.9	7.9	12.1	11.4	"
Education & farm trading	low	37	6.1	6.5	7.6	5.0	"
Total		165					
Lead & zinc mining & smelting	highest	27		45.9	80.2	109.4	"
Lead & zinc smelting	high	17		19.2	32.2	29.2	"
Copper smelting	low	28		11.2	14.3	12.5	"
Government & commercial	low	9		7.3	13.5	13.2	"
Education & farm trading	low	21		6.8	8.2	5.2	"
Total		102					

(Continued)

TABLE A-11. LEAD IN HUMAN HAIR (Continued)

Panama	184 males	age 0-10 yrs. ppm	age 11-20 yrs. ppm	age 20 yrs. ppm	Klevay (1973)
Panama City	(arith. mean)	46.3	21.4	29.9	"
Panama	"	52.1	30.6	33.5	"
Darien	"	20.7	22.7	5.4	"
Cocle	"	27.0	6.0	36.5	"
Herrera	(arith. mean)	8.9	7.8	15.1	"
Nat. Guard	"	---	6.0	9.2	"
Chiriqui	"	28.2	1.1	8.9	"
Los Santos	"	13.8	6.3	4.5	"
Veraguas	"	9.0	4.6	3.3	"
	For all 184 males and arith. mean was 24.5, geom. mean 12.1±S.D. 0.32				"
	242 non-pregnant, non-lactating females	age 0-10 yrs.	age 11-20 yrs.	age 20 yrs.	
Panama City	(arith. mean)	78.7	45.1	55.0	"
Panama	"	66.4	37.7	42.7	"
Darien	"	24.8	26.6	19.4	"
Cocle	"	29.6	23.3	17.9	"
Herrera	"	14.1	18.8	14.3	"
Chiriqui	"	16.5	16.4	17.8	"
Los Santos	"	16.0	8.7	14.6	"
Veraguas	"	8.3	18.3	12.7	"

TABLE A-12. LEAD IN HUMAN NAILS

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
United States	18 male "normals," white, age 15-70 yrs.	0.97-2.4	Goldblum et al. (1953)
United States	Pb occurred in 98% of nail samples, with levels 10-100 times greater than normal Pb blood levels		Cooper Langford (1972)

TABLE A-13. MERCURY IN HUMAN HAIR

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
New York	115 dentists	(1.0-34.0)	Gutenmann et al. (1973)
" "	115 dentists, 89% above "normal" of 2.5		"
New York	41 with tuna & swordfish diets	(0.8-40.7)8.8	McDuffie (1971)
" "	19 non-tuna diet (control)	(0.9-12.8)3.1	"
" "	Tuna and swordfish dieters:		
	9-16 µg Hg/150 lb men/day (Hg in blood)	(blood) (hair) 0.006 5.3	"
" "	17-26 µg Hg/150 lb men/day (Hg in blood)	0.0064 4.9	"
" "	27-38 µg Hg/150 lb men/day (Hg in blood)	0.012 9.4	"
" "	40-75 µg Hg/150 lb men/day (Hg in blood)	0.0173 14.4	"
New York	Scalp hair Hg levels of adults and children were significantly correlated with environmental exposure gradients		Creason et al. (1975)
Buffalo	Urban areas	1.49±2.18	Cited in Giovanoli-Jakubzak (1974)
"	Rural areas	1.01±1.53	"
New York Rochester	12 "normals", age 4-48 yrs.	0.88±0.34	Giovanoli-Jakubzak (1974)
"	9 occupationally exposed age 25-40 yrs.	2.13±0.67	"
"	4 Japanese living in Rochester, age 3-32 yrs.	1.71±0.14	"

(Continued)

TABLE A-13. MERCURY IN HUMAN HAIR (Continued)

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
New York Rochester	Hair Hg levels of "normals" are 350 times levels in blood		Giovanoli-Jakubzak (1974)
Tennessee	33 adult and children "normals"	(0.1-33.0)7.6±1.4	Bate & Dyer (1965)
Nashville	230 mothers	D 1.38 (median)	Baglan et al. (1974)
"	94 infants, age 6 wks.	D 2.59 (median)	"
Ohio Cleveland	3 males	2.41±1.32	Yamaguchi et al. (1971)
"	4 females	1.61±0.32	"
Michigan	12 males, washed hair 2 X/mo.	2.1	Gordus et al. (1975)
"	12 males, washed hair 20 X/mo.	3.1	"
"	41 females, age 18-22 yrs. 1972	2.8	"
United States	27 females, age 12-40 yrs. 1910-1935	1.6	"
" "	11 females, age 12-40 yrs. 1890-1910	1.8	"
" "	10 females, age 12-40 yrs. before 1890	3.5	"
Idaho	1,000 residents:	(0.12-139.0)4.18	Benson & Gabica (1972)
"	males, (ave.)	2.45	"
"	females, (ave.)	5.9	"
"	male, age 1-10 yrs.	(0.26-8.0)2.04	"

(Continued)

TABLE A-13. MERCURY IN HUMAN HAIR (Continued)

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
Idaho	female, age 1-10 yrs.	(0.56-12.0)3.21	Benson & Gabica (1972)
"	male, age 11-20 yrs.	(0.13-107.0)3.28	"
"	female, age 11-20 yrs.	(0.25-104.0)6.99	"
"	male, age 21-40 yrs.	(0.33-17.6)2.01	"
"	female, age 21-40 yrs.	(0.24-43.8)4.92	"
"	male, age 41-60 yrs.	(0.2-100.0)2.37	"
"	female, age 41-60 yrs.	(0.26-139.0)7.64	"
"	male, age 61+ yrs.	(0.12-24.6)2.55	"
"	female, age 61+ yrs.	(0.64-120.0)6.72	"
Texas Port Arthur	25 males, age 9-60 yrs. near refineries	(0.2-12.4)6.2	Eads & Lambdin (1973)
" "	20 females, age 13-72 yrs.	(0.1-30.0)5.5	"
" "	1 female, age 29 yrs.	139.0	"
California Angwin	23 college students, some used pool	(0.3-60.5)3.46±3.04	Martz & Larsen (1973)
"	22 children used swimming pool treated with algacide phenylmercuric acetate	(ave.) 39.6±38.2	"
"	15 children did not use pool	(ave.) 3.43±1.79	"
"	37 children	(ave.)(1.1-135.9)24.9±34.3	"
"	13 adults	(ave.)(0.6-3.3)1.64±0.81	"
California	1 fish eater with interrupted diet	4.4	Giovanoli-Jakubzak (1974)
Pasadena	98 women	(ave.) 29.6	Nord et al. (1973)

(Continued)

TABLE A-13. MERCURY IN HUMAN HAIR (Continued)

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
Pasadena	98 women	(geom. mean) 25.0	Nord et al. (1973)
"	98 women	(range)(5.0-410.0)	"
"	woman	(max.) 410.0	"
New Mexico Los Alamos	woman	(max.) 680.0	"
"	80 men	(ave.) 20.1	"
"	80 men	(geom. mean) 18.0	"
"	145 women	(ave.) 20.8	"
"	146 women	(geom. mean) 18.9	"
California	64 white males	(0.0-6.0)1.6	Verghese et al.(1973)
"	51 white females	(0.0-18.0)6.0	"
New Mexico Alamorgordo	Huckelby family ate pork fed Hg contaminated grain		Krehl (1972)
	Father	186.1	"
	Dorothy Jean	2,436.0	"
"	Mother ate Hg contaminated pork in early pregnancy	186.0	Pierce et al. (1972)
"	Child had myoclonic convulsions, could not sit up and was blind		"
United States	"normal"	10.0	Eyl et al. (1970)
" "	Highest levels found	96.0-185.0	Cited in Nord et al. (1973)
" "	Fatal case	500.0	
United States	"normals"	0.01-2.5	Joselow et al. (1972)

(Continued)

TABLE A-13. MERCURY IN HUMAN HAIR (Continued)

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
United States		6.0	Schroeder & Nason (1971)
United States	32 males, age 18-22 yrs. in Navy	means 2.2	Gordus et al. (1974)
" "	32 males, age 18-22 yrs. 5 mos. later	1.5	"
" "	32 males, age 18-22 yrs. 12 mos. later	1.8	"
" "	119 males, age 18-22 yrs. in Navy	1.9	"
" "	71 males, age 18-22 yrs. 5 mos. later	1.7	"
" "	56 males, age 18-22 yrs. 17 mos. later	1.7	"
" "	14 females, 1800-1899	3.6	"
" "	43 females, 1900-1930	2.0	"
Alaska Coastal	17 Eskimo females ate much marine mammal meat	4.257±0.621*	Galster (1975)
Alaska Inland	11 female Eskimoes	3.574±0.740*	"
Anchorage	10 female Eskimoes	4.045±0.796*	"
		*expressed as nanograms/g	
Pribilof Is. Alaska	13 Eskimoes ate seal liver and muscle	5.0-6.0	USPHS (1970)
Canada	Ate contaminated fish	75% "high levels"	Jervis et al. (1970)
"	Small group	1.1-55.3	Perkons & Jervis (1965)

(Continued)

TABLE A-13. MERCURY IN HUMAN HAIR (Continued)

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
Canada	An individual, 1947	8.0	Jervis et al. (1965)
"	Same individual, 1961	53.3	"
"	600 persons	(0.0-19.0)1.7±0.98	"
"	776 ate contaminated fish several times week	50.0-100.0	"
"	"Normal" population	(1.0-3.0) statistical mode 1.5	Perkons & Jervis (1966)
Ontario Kenora	9 ate no fish	(2.0-14.0)	Mastromatteo Sutherland (1972)
"	21 ate some fish	<10.0	"
"	9 persons	10.0-25.0	"
"	3 persons	25.0-50.0	"
"	4 persons	50.0-100.0	"
"	Person with high recent fish consumption	96.0	"
Lake St. Clair	5 persons	(2.0-9.1)	"
" " "	Female ate fish 2-5 x/week	49.9	"
Northwest Territory Yellowknife	12 residents 1.5-23 yrs.	(3.96-78.8)6.9	O'Toole et al. (1971)
St. Lawrence River	2 persons ate fish 3-4 x/week	(2.0-5.0)	Mastromatteo & Sutherland (1972)
Alberta	Female used shampoo with 80 and 124 ppm Hg	118.0	Wilson et al. (1974)
"	Male used shampoo with 80 and 124 ppm Hg	47.0	"

(Continued)

TABLE A-13. MERCURY IN HUMAN HAIR (Continued)

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
Alberta	Survey	(1.0-5.6)1.5	Wilson et al
"	"Control"	2.34	"
"	"Control" washed in detergent	1.94	"
Canada	"Controls," unexposed	0.2-6.0	Jervis et al. (1970)
"	Occupational exposure to Hg	5.0-10.0	"
"	45 urban residents, Toronto	(0.24-5.2)2.0 med.	Chattopadhyay & Jervis (1974)
"	76 rural residents, central Canada	(0.28-2.5)1.2 med.	"
"	121 urban near refineries	(0.2-5.5)2.3 med.	"
Mexico Zacatecas	Hg smelting worker age 70 yrs. exposed 20 yrs.	38.01	De la Pina (1975)
"	Hg smelting worker age 45 yrs. exposed 5 yrs.	3.89	"
"	Hg smelting worker age 35 yrs. exposed 7 yrs.	5.4	"
"	Hg smelting worker age 32 yrs. exposed 15 yrs.	30.93	"
"	Hg smelting worker age 30 yrs. exposed 18 yrs.	48.85	"
"	Hg smelting worker age 45 yrs. exposed 3 yrs. (but had not worked for 1 yr.)	0.96	"
Querétero	Hg smelting worker age 35 yrs. exposed for 2 yrs. (but had not worked for 8 yrs.)	5.32	"

(Continued)

TABLE A-13. MERCURY IN HUMAN HAIR (Continued)

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
Queretero	Hg smelting worker age 43 yrs. exposed 5 yrs.	3.1	De la Pina (1975)
Mexico City	6 "controls" (ages 20-70 yrs.)	(1.48-2.14)1.9±S.D. 0.11	"
Mexico	Smelter worker, hair sample before washing	14.7	"
"	After washing	5.6	"
Venezuela Upper Orinoco	24 Yanomamo indians	(0.3-1.4)1.0±0.3	Hecker et al. (1974)
Venezuela	11 Amazonian indians	(1.7-4.15)2.98	Perkons (1977)
Bolivia	Japanese who emigrated had very low Hg hair levels after living in Bolivia		Suzuki et al. (1972)
Sweden	4 "normals"	1.3	Löfroth (1969)
Lake Vanern	51 fish eaters ate 0.45 kg/wk (0.84 ppm in fish)	(0.81-31.0)7.9±S.E. 0.85	Tejning (1970)
" "	22 fish eaters ate 0.45 kg/wk	10.131±S.E. 1.563	"
" "	1-60 yr. fishermen ate 0.75 kg. of fish daily	27.6-46.6)	"
Sweden	"Normal" never ate fish	<2.0	Berglund et al. (1971)
"	"Normal", never ate fish	0.92	Tejning (1970)
"	5 "normals"	1.6	Birke et al. (1967)
"	4 "normals"	1.35	"
"	0.15 mg. intake of Hg/day from fish	40.0	Birke et al. (1972)

(Continued)

TABLE A-13. MERCURY IN HUMAN HAIR (Continued)

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
Sweden	0.1 mg intake of Hg/day from fish	31.0	Birke et al. (1972)
"	0.036 mg intake of Hg/day from fish	8.7	"
"	0.015 mg intake of Hg/day from fish	2.2	"
"	0.815 mg intake of Hg/day from fish	185.0 (160.0 MeHg)	"
"	0.11 mg intake of Hg/day from fish	15.0 (13.0 MeHg)	"
"	12 persons	(1.0-180.0)	"
"	Biological half life of Hg in hair is (65-250) ave. 160 days; after subtraction of background it is (33-120) ave. 80 days. In Japanese data on hair, the Hg half life is 60-70 days.		"
"	Threshold effect of Hg is 0.2-0.3 ppm of Hg in blood equivalent to hair of --	(50.0-90.0)	Skerfving (1972a & b)
"	Biological half-life of methylmercury in man is 200 days based on studies of hair of fish eaters who stopped eating fish		Westermark (1969)
"	Equivalent to level of 0.2 ppm Hg in blood	60.0	Skerfving et al. (1969)
"	29 ate 450 g. contaminated fish/week	6.222±S.E. 0.809	Tejning (1970)
"	51 ate 450 g. contaminated fish/week	(0.81-31.0)7.9± S.E. 0.85	"
"	1 ate 220 g. contaminated fish/week	3.1	"
"	22 ate 450 g. contaminated fish/week	10.131±S.E. 1.563	"

(Continued)

TABLE A-13. MERCURY IN HUMAN HAIR (Continued)

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
Sweden	7 ate 450-1400 g. contaminated fish/week	(1.0-11.2)	Tejning (1970)
"	17 ate 35-3, 030 g. contaminated fish/week	(3.9-33.8)	"
"	18 ate "high" amount of fish/week	(2.2-185.0)	"
"	3 ate 2,000 g. contaminated fish/week	(6.8-56.0)	"
"	0.3 mg. Hg/day/70 kg man (equivalent to 0.2 ppm in blood)	60.0	Berglund et al. (1971)
"	Hair to blood ratios for methyl-Hg are approximately 300		"
"	Safety factor of 10, safe level	6.0	"
Finland	3 non-fish eaters	(0.3-4.3)2.3	Sumari et al. (1969)
"	20 fish eaters ate fish with 1.0-5.0 ppm Hg	(3.0-56.0)17.3	"
"	Ate 300 g fish/day	56.0	"
"	Ate 300 g fish/day	26.9	"
"	Ate 150 g fish/day	6.8	"
"	Ate 135 g fish/day	11.5	"
"	Ate 65 g fish/day	15.4	"
"	Ate 65 g fish/day	15.5	"
"	Ate 55 g fish/day	11.1	"
"	Ate 50 g fish/day	8.2	"
"	Ate 35 g fish/day	26.7	"

(Continued)

TABLE A-13. MERCURY IN HUMAN HAIR (Continued)

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
Finland	Ate 20 g fish/day	14.0	Sumari et al. (1969)
"	Ate 5 g fish/day	33.8	"
"	Ate 5 g fish/day	7.7	"
"	Female, age 45 yrs., ate goosander eggs containing (0.3-3.5)1.4 ppm Hg	2.8	Wahlberg et al. (1971)
"	"Normals" in Finland	1.5	"
Italy Naples	4 fishermen & families methyl Hg	(0.34-0.86)0.52	Ui & Kitamura (1971)
"	4 fishermen & families total Hg	(1.52-2.22)1.86	"
Italy Cesenatico	2 fishermen & families methyl Hg	(3.07-4.76)3.92±S.D. 0.83	Ui & Kitamura (1971)
"	2 fishermen & families total Hg	(3.93-5.96)4.95±S.D. 0.99	"
Porto Corsini	10 fishermen & families methyl Hg	(0.45-5.53)3.54±S.D. 1.5	"
" "	10 fishermen & families total Hg	(1.56-11.61)5.8±S.D. 3.01	"
Marina di Ravenna	1 fisherman (near factory discharge) methyl Hg	5.25	"
"	Total Hg	7.54	"
Casal Borsetti	10 fishermen & families, methyl Hg	(1.33-5.69)2.19±S.D. 1.28	"
" "	10 fishermen & families, total Hg	(1.84-9.42)4.31±S.D. 2.29	"

(Continued)

TABLE A-13. MERCURY IN HUMAN HAIR (Continued)

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
Tuscany	7 male Hg smelter workers (high exposure)	(7.6-50.0)25.0±S.E. 6.1	Cigna Rossi et al. (1976)
"	13 male Hg miners	(1.4-8.8)4.0±S.E. 0.8	"
"	12 male unexposed "normals"	(0.8-4.5)1.8±S.E. 0.3	"
"	Hg content of hair was correlated with the Hg exposure levels		"
Amiata Mt.	8 residents	(0.9-4.5)1.8±S.D. 1.1	Cagnetti et al. (1974)
France Nice	4 fishermen & families, methyl Hg	(0.75-7.16)3.03±2.48	Ui & Kitamura (1971)
"	4 fishermen & families, total Hg	(1.58-7.39)3.88±2.15	"
Ireland	14 rural children near zinc copper mine	ave. 0.48	Corridan (1974)
"	20 urban children, unexposed	(0.05-0.69)0.215	"
Scotland Glasgow	70 "normals" died of violence	(0.03-24.0)5.52	Howie & Smith (1967)
"	"Normals", no known exposure to Hg	5.0-8.0	"
Great Britain	840 subjects:		
	female (ave.)	5.1±S.D. 0.37	Coleman et al. (1967)
" "	male (ave.)	6.9	"
" "	Daily intake 7.5 µg/man/day	2.88	Ministry of Agr. (1971)
Scotland Glasgow	82 residents	(0.37-16.5)3.38±S.D. 3.4 2.41 geom. mean	Dale et al. (1975)

(Continued)

TABLE A-13. MERCURY IN HUMAN HAIR (Continued)

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
Great Britain			
	adults not occupationally exposed (ave.)	4.0	Lenihan et al. (1971)
Poland			
Warsaw	12 "normals," age 25-65 yrs.	0.69±0.31	Giovanoli-Jakubczak (1974)
"	7 exposed to Hg, age 30-55 yrs.	1.39±0.87	"
Cracow	15 "normals" 17-67 yrs.	0.59±0.18	"
Gdynia	5 "normals" 0.4-40 yrs.	0.75±0.21	"
Yugoslavia			
Idrija	3 males	(0.15-1.97)0.79	Byrne et al. (1971)
"	3 females	(0.15-0.51)0.27	"
"	1 male, age 3 yrs.	0.086	"
"	1 male, beard	0.412	"
"	workers' & students' beards, 11	(0.5-4.2)2.24	Kosta et al. (1972)
Iraq	Several hundred people:		Al-Shahristani & Al-Haddad (1972)
	"Normal" uncontaminated areas	(0.1-4.0)1.0	
"	Contaminated areas	(1.0-12.0)4.0	"
"	Consumed methyl-Hg contaminated grain, no symptoms	5.0-300.0	"
"	Consumed methyl-Hg contaminated grain, mild symptoms (slight tremor, mild ataxia, blurred vision)	120.0-600.0	"

(Continued)

TABLE A-13. MERCURY IN HUMAN HAIR (Continued)

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
Iraq	Consumed methyl-Hg contaminated grain, moderate symptoms (partial paralysis, tunnel vision, hearing problems, and disarticulation)	200.0-800.0	Al-Shahristani & Al-Haddad (1972)
"	Consumed methyl-Hg contaminated grain, severe symptoms (complete paralysis, loss of vision, loss of hearing, loss of speech, coma)	400.0-1,600.0	"
"	Consumed methyl-Hg contaminated grain, age 60 yrs., no obvious symptoms	1,000.0	"
"	Consumed methyl-Hg contaminated grain, age 60 yrs., no obvious symptoms	1,065.0	"
Bagdad	100 persons	(0.1-5.5)1.0,1.3 med.	Al-Shahristani & Al-Haddad (1973)
"	1 "normal" age 30 yrs.	1.0	Giovanoli-Jakubczak (1974)
Iraq	175 rural & urban residents	(<0.09-5.0)0.82	Al-Shahristani (1976)
"	2 patients Hg poisoned	550.0, 725.0	Bakir et al. (1973)
Iraq villages	3 aged 25-30 ate bread made with methylmercury coated wheat for 2-2.5 mos.:		Giovanoli-Jakubczak & Berg (1974)
"	female	649.0	"
"	female	564.0	"
"	female	535.0	"

(Continued)

TABLE A-13. MERCURY IN HUMAN HAIR (Continued)

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
Iraq	385 persons who ate Hg contaminated bread, >5 years of age	136.0±S.E. 17.8	Kazantzis et al. (1976a)
"	1,160 persons who did not eat Hg contaminated bread, >5 yrs. of age	5.0±S.E.0.8	"
Nepal Silgarhi Doti & Dhangarhi	31 males, ate no fish	0.163±0.187	Yamaguchi et al. (1971)
"	14 females, ate no fish	0.457±0.484	"
Burma	Japanese who emigrated to Burma had a decrease of Hg in hair		Suzuki et al. (1972)
East Pakistan	After 10 mo. in Bangladesh there was no significant decrease in Hg in hair of emigrated Japanese. Bangladesh people had about same Hg hair level as Japanese		"
Japan	67 male "normals"	(0.0-11.99)4.48	Yumaguchi et al. (1971)
"	27 female "normals"	(1.0-7.99)3.53	"
"	94 "normals"	(0.0-11.99)4.21	"
"	14 male Americans living in Fukuoka, Japan	(0.69-4.23)1.89±1.04	"
Japan	24 persons	4.6±1.94	Aoki (1970)
"	12 male patients in mental hospitals	(1.0-3.19)2.09	Yamaguchi et al. (1971)
"	21 female patients in mental hospitals	(0.69-3.05)2.02	"
"	6 males, hair unwashed	(4.75-16.1)11.1	"

(Continued)

TABLE A-13. MERCURY IN HUMAN HAIR (Continued)

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
Japan	6 males, after washed	(0.89-3.72)2.71	Yamaguchi et al. (1971)
"	9 females, hair unwashed	(2.36-17.59)5.69	"
"	9 females, after washed	(1.56-6.44)4.48	"
"	12 persons	(4.1-146.0)	Saito (1967)
"	22 victims of Minamata disease	(15.6-763.0)	"
"	22 victims of Minamata disease (had 1.32 ppm Hg in blood)	430.0	Saito (1967)
"	Niigata victims of Minamata disease	(52.0-570.0)	Takeuchi (1972a & b)
"	Niigata victims showed symptoms, long time after onset	10.0-20.0	"
"	Niigata, onset of Minamata disease	200.0	Berglund et al. (1971)
"	2,500 persons examined, 127 persons	>50.0	"
"	2,500 examined, 36 persons	>100.0	"
"	2,500 examined, 6 persons	>200.0	"
"	Consumption of 0.3 mg Hg/day in fish	50.0	Berglund et al. (1971)
"	Minamata diseased persons	500.0	Birke et al. (1967)
"	Highest Minamata diseased person	750.0	Krehl (1972)
"	Analysis of segments of long hair enabled determination of peak period of Hg intake		Irukayama (1966)

(Continued)

TABLE A-13. MERCURY IN HUMAN HAIR (Continued)

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
Japan	Persons dying with Minamata disease	(14.0-39.0)	Kurland et al. (1960)
"	Minamata disease victims	515.0	Berglund & Berlin (1969)
"	" " "	565.0	"
"	" " "	763.0	"
"	15 members of their families	15.0-412.0	"
"	Severe intoxication	700.0	Skerfving et al. (1970)
"	Threshold of mercury effects	200.0	"
"	Inhaled Hg vapors, hair near scalp	20.4	Ota (1966)
"	Inhaled Hg vapors, hair near scalp 7 mos. later	4.6	Ota (1966)
"	Unexposed workers	1.9-6.2	"
"	94 "normals"	(<0.99-12)4.2	Yamaguchi & Matsumoto (1968)
"	73 "normals"	(0.98-23.0)6.0±S.D. 2.9	Hoshino et al. (1966)
Japan Tokyo	7, fish eaters, age 15-32 yrs.	6.2±2.0	Giovanoli-Jakubczak (1974)
Japan	Minamata Bay, fatalities (calculated 300-1 blood-hair ratio)	369.0	Dinman & Hecker (1972)
"	Niigata, 22 persons with Minamata disease	(56.8-570.0)239.08	Tsubaki (1969)
"	Kumamoto, 25 persons with Minamata disease	(2.46-705.0)138.2	Kitamura et al. (1960)

(Continued)

TABLE A-13. MERCURY IN HUMAN HAIR (Continued)

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
Japan	Threshold for signs and symptoms of methyl mercury poisoning (equivalent to 0.2 ppm in blood)	50.0	Berglund et al. (1971)
"	Threshold effect of Japan and Sweden fish eaters (equivalent to 0.2-0.3 ppm in blood)	50.0-90.0	Skerfving (1972a & b)
"	74 "normals"	6.02	Ukita (1968)
"	101 Tokyo citizens	(1.0-15.0)3.85	Nishima et al. (1971)
"	52 Tokyo males	6.35±4.04	"
"	49 Tokyo females	3.9±1.04	"
"	104 Tokyo males	(2.6-17.7)6.9±2.8	"
"	87 Tokyo females	(1.0-7.8)3.8±1.5	"
"	Male fish retailer (ate 200 g tuna 7 x/wk.; ate 1000 g other fish 7 x/wk)	64.7	Press Release (1973)
"	Male fish retailer (ate 100 g tuna 3 x/wk; ate 80 g other fish 7 x/wk)	44.4	"
"	Fish retailer (ate 100 g tuna 7 x/wk; ate 100 g other fish 7 x/wk)	41.2	Press Release (1973)
"	178 residents ate 84 g fish/day		Yamaguchi et al. (1971)
"	111 males	4.35±2.45	"
"	67 females	3.94±2.03	"
Ikitsuki Island	89 tuna fishermen	4.83±2.31	"

(Continued)

TABLE A-13. MERCURY IN HUMAN HAIR (Continued)

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
Niigata Bay	45 (7 subjects above 180 ppm)	(20.0-325)	Tsubaki (1972)
"	Fish eaters, 735 (intake of 0-0.8 mg/day)$y_2 = 150 x + 1.66$		Kojima & Araki (1972)
Japan	"Normal" Japanese	4.22±2.39	Akitake (1969)
"	Americans living in Japan	1.89±1.04	"
"	Occupationally exposed	5.67±1.61	"
"	Tungsten refinery workers	10.1±1.7	"
"	Minamata disease patients 8-9 yrs. after onset	23.85±14.87	"
"	Hg was higher in males than females		Suzuki et al. (1972)
"	15 farmers	7.5±4.8	Ohno et al. (1967)
"	8 dental doctors	9.8±2.9	"
"	Tokyo citizens:		Nishima et al. (1973)
"	62 males ate rice 3 x/day	6.99	"
"	32 females ate rice 3 x/day	3.94	"
"	34 fish eaters ate rice 3 x/day	20.75	"
"	32 males ate rice 1-2 x/day	6.87	"
"	51 females ate rice 1-2 x/day	3.74	"
"	45 fish eaters ate rice 1-2 x/day	18.62	"
"	3 male bread eaters	5.63	"
"	4 female bread eaters	2.9	"

(Continued)

TABLE A-13. MERCURY IN HUMAN HAIR (Continued)

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
Japan	1 bread and fish eater	34.4	Nishima et al. (1973)
"	65 males prefer fish-eating	7.54	"
"	42 females prefer fish-eating	4.21	"
"	70 prefer fish-eating, heavy fish consumers	20.52	"
"	38 males did not prefer fish-eating	5.79	"
"	45 females did not prefer fish-eating	3.37	"
"	10 heavy fish consumers	14.12	"
"	Japanese intake 45.6 μg/man/day	5.14	Takizawa (1974)
River Oyabe	83.6 μg/man/day or 15.6 methyl-Hg μg/man/day	6.69 methyl-Hg	"
" "	Heavy fish-eaters near River, 193.7 μg/man/day	17.2	"
Japan	Japanese crew tuna fishing boat 119.1 μg/man/day	19.9	"
"	Japanese Niigata patients 1,481.7 μg/man/day	249.5	"
"	3 inhabitants in polluted district of Niigata:		"
	758.7 μg/man/day	116.8	
	216.7 μg/man/day	40.1	
	49.7 μg/man/day	18.4	
Japan Kumamoto	1,645 persons living near polluted area:		Matsushima & Doi (1962)
"	85 persons	0-1.0	"

(Continued)

TABLE A-13. MERCURY IN HUMAN HAIR (Continued)

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
Japan Kumamoto	255 persons	1.0-10.0	Matsushima & Doi (1962)
"	1,044 persons	10.0-50.0	"
"	245 persons	50.0-100.0	"
"	35 persons	100.0-150.0	"
"	6 persons	150.0-200.0	"
"	1 person	200.0	"
"	1 person	233.0	"
"	1 person	357.0	"
"	1 person	600.0	"
"	1 person	920.0	"
Indian Ocean	5 crew on tuna boat ate 300 g tuna/day	(30.3-45.7)45.0	Yamanaka et al. (1972)
"	58 male tuna fishermen	(7.0-45.7)19.9±9.9	"
Japan Tokyo	22 male and female fish market workers	(2.58-25.6)10.7±5.5	Doi (1973)
"	92 male sushi makers	(to 52.0)14.8±6.12	Nishima et al. (1971)
"	84 male fish dealers	(4.7-64.7)19.3±10.4	Nishima et al. (1973)
"	63 male tuna fishermen	(5.2-69.0)24.4±13.2	"
"	37 male tuna fishermen	(4.8-39.7)18.9±9.0	Kondo & Takehiro (1973)
Samoa Western Shore	11 fish eaters (age 24-46 yrs.)	7.2±2.2	Giovanoli-Jakubczak (1974)

(Continued)

TABLE A-13. MERCURY IN HUMAN HAIR (Continued)

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
New Zealand Hastings	"Normals" 33 boys, elementary school	(0.3-34.0)2.2±S.D. 1.3	Bate & Dyer (1965)
Napier	"Normals" 33 boys, elementary school	(0.5-5.3)1.8±S.D. 0.88	"
15 Countries	70 persons	(0.03-24.4)	Goldwater (1972)
		5.52±S.D. 5.21	Liebscher & Smith (1968)
Country Unspecified	26 of 37 persons exceeded 6 ppm (acceptable level of Berglund)		Lambou (1972)
15 Countries	"Normal" no known exposure:		Rodger & Smith 1967)
	head hair	5.5	
	pubic hair	1.6	
	From 12 countries other than Japan	(0.89-4.19)	Saito (1967)
Country Unspecified	Dental assistants	Ave. 32.0	Underwood (1973)
"	Industrial workers in contaminated laboratory	to 98.0	"
"	For methylmercury, the conc. in hair ratio to conc. in blood is 250. The concentration ratio relationship between conc. of Hg in hair and whole blood is from 230 to 280 based on analysis of 123 subjects		Clarkson (1976)

TABLE A-14. MERCURY IN HUMAN NAILS

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
Country Unspecified	25	(0.8-33.8)	Goldwater (1972)
		7.27±S.D. 8.39	Liebscher & Smith (1968)
"	No known exposure:		Rodger & Smith (1967)
	fingernails	7.3	
	toenails	2.4	"
"	Hg in nails determined		Cooper & Langford (1972)
Pennsylvania	Patients with certain dermatological conditions have more pigmentation of nails after treatment with ammoniated Mercury ointment. The dermatoses include psoriasis, seborrheic dermatitis, alopecia areata, atopic & stasis dermatitis, & pitting of nails		Butterworth & Strean (1963)
Country Unspecified	Determined fingernail cystine content in persons with chronic mercury exposure		Kleinfeld et al. (1961)

TABLE A-15. NICKEL IN HUMAN HAIR

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
United States New Hampshire	63 males, natural color hair	1.07±0.178	Schroeder & Nason (1969)
" "	24 females, natural color hair	4.09±1.091	"
" "	16 males, grey & white	0.54±0.088	"
" "	1 female, grey & white	1.0	"
" "	15 males, red hair	1.74±0.618	"
" "	7 females, red hair	3.19±0.424	"
" "	All ages	(0.0-11.0)	"
New York	Ni in scalp hair of children only only was correlated with environmental exposure gradients		Creason et al. (1975)
Country Unspecified	Clipped hair 2-5 cm from scalp used for environmental and occupational exposures to Ni		Nechay & Sunderman (1973)
North East United States	30 male residents	1.01±S.D. 0.44	Katz & Samitz (1974)
" "	30 female residents	4.21±S.D. 1.0	"
New York Riverhead	43 samples	0.569	Pinkerton et al. (1973)
Queens	31 samples	0.849	"
Bronx	28 samples	0.726	"
United States Various areas	12 persons, age 12-69 yrs.	(0.8-15.6)3.7	Hinners et al. (1974)
"	52% Ni was extracted from hair by 1% HNO_3		"
Texas	22 males, age 9-60 yrs.	(0.9-7.2)1.9	Eads & Lambdin (1973)

(Continued)

TABLE A-15. NICKEL IN HUMMAN HAIR (Continued)

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
Texas	21 females, age 13-72 yrs.	(0.7-7.5)3.4	Eads & Lambdin (1973)
United States		0.0075	Schroeder & Nason (1971)
United States	32 young males in Navy	(means) 2.8	Gordus et al. (1974)
" "	32 young males, 5 mos. later	3.4	"
" "	32 young males, 17 mos. later	3.5	"
" "	124 young males	(medians) 3.2	"
" "	70 young males, 5 mos. later	3.2	"
" "	56 young males, 17 mos. later	2.8	"
" "	14 females, 1800-1900	2.7	"
" "	43 females, 1900-1930	3.2	"
United States	41 females, age 18-22 yrs., U. Mich. 1972	(geom. means) 6.3	Gordus et al. (1975)
" "	27 females, age 12-40 yrs. 1910-1935	4.0	"
" "	11 females, age 12-40 yrs. 1890-1910	2.5	"
" "	10 females, age 12-40 yrs. before 1890	3.1	"
" "	Preliminary data show a significant increase of Ni in hair of females age 12-40 yrs. from before 1890 to the present.		"

(Continued)

TABLE A-15. NICKEL IN HUMAN HAIR (Continued)

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
Canada	45 urban residents of Toronto	(1.2-20.0)2.4 med.	Chattopadhyay & Jervis (1974)
"	76 rural residents of Central Canada	(1.6-17.0)2.1 med.	"
"	121 urban near refineries	(1.1-32.0)3.6 med.	"
Venezuela	11 Amazonian indians	(43.0-71.0)59.0 med.	Perkons (1977)
Germany	Nickel workers scalp hair	0.2-0.96	Hagedorn-Götz & Kuppers (1975)
German Democratic Republic	5 workers breathed Ni carbonyl (first 10-15 days after exposure)	(4.0-48.1)25.2	Hagedorn-Götz et al. (1977)
" "	5 workers (15 to 170 days after exposure)	(0.4-17.5)3.0	"
" "	The half-life of Ni in hair is	23.7±S.D. 5.0 days	"

TABLE A-16. SELENIUM IN HUMAN HAIR

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
United States Tennessee	33 adults and children	(1.0-11.0)6.4	Bate & Dyer (1965)
United States	Males	0.3	Schroeder & Nason (1971)
" "	Females	13.0	"
Country Unspecified	People lose hair from high Se		Rosenfeld & Beath (1964)
"	Organic selenosis occurs in people in seleniferous areas. Hair levels of affected persons are	8.0-30.0	Oelschlager (1970)
New York	Se was measured in scalp hair of adults and children, but no correlation was found with environmental exposure		Creason et al. (1975)
United States	Females, age 3-5 yrs., brown	0.6	Schroeder et al. (1970)
" "	Male, age 7 yrs., red	0.5	"
" "	Male, age 16 yrs., ash brown	0.55	"
" "	Female, age 23 yrs., red brown	0.58	"
" "	Male, age 49 yrs., dark brown	0.74	"
" "	Female, age 68 yrs., grey	0.61	"
" "	Female, age 71 yrs., grey	0.36	"
" "	Male, age 84 yrs., black & white	0.60	"
" "	Mean	0.57±0.038	"

(Continued)

TABLE A-16. SELENIUM IN HUMAN HAIR (Continued)

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
United States	Male--beard hair of man using Se medication for face & skin	23.0	Fuller et al. (1967)
" "	Use of Se disulfide shampoo makes hair unreliable as index of Se toxicity in man		"
United States	32 young males in Navy	means 0.97	Gordus et al. (1974)
" "	32 young males, 5 mos. later	1.06	"
" "	32 young males, 17 mos. later	1.15	"
" "	121 young males	medians 0.76	"
" "	71 young males, 5 mos. later	0.66	"
" "	56 young males, 17 mos. later	0.58	"
	Some men used Se-containing hair shampoo and some had over 2.0 ppm Se		"
" "	Females, 14 samples, 1800-1900	0.58	"
" "	Females, 41 samples, 1900-1930	0.55	"
Michigan	12 males, washed hair 2 x/mo.	geom. means 0.76	Gordus et al. (1975)
"	12 males, washed hair 20 x/mo.	0.80	"
"	41 females, age 18-22 yrs., 1972	0.54	"
United States	27 females, age 12-40 yrs., 1910-1935	0.62	"
" "	11 females, age 12-40 yrs., 1890-1910	0.47	"
" "	10 females, age 12-40 yrs., before 1890	0.62	"

(Continued)

TABLE A-16. SELENIUM IN HUMAN HAIR (Continued)

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
Canada		(1.0-2.5)	Perkons & Jervis (1965)
Yellowknife	12 residents in Yellowknife, 1.5-23 yrs.	(1.72-5.64)2.7	O'Toole et al. (1971)
Canada	45 urban residents of Toronto	(0.29-6.3)1.9 med.	Chattopadhyay & Jervis (1974)
"	76 rural residents of Central Canada	(0.32-4.8)1.8 med.	"
"	121 urban near refineries	(0.27-7.4)2.3 med.	"
Venezuela	11 Amazonian indians	(2.15-5.45)3.68, 3.15 med.	Perkons (1977)
Central & South America	Alopecia occurs in people in high seleniferous areas		Rosenfeld & Beath (1964)
Italy Tuscany Amiata Mt.	7 males, Hg smelter workers	(0.213-0.664)0.449 ±S.E. 0.13	Cigna Rossi et al. (1976)
"	13 males, Hg miners	(0.41-0.45)0.43 ±S.E. 0.021	"
"	12 males, unexposed "normals"	(0.218-0.505)0.332 ±S.E. 0.061	"
"	Se content in blood was higher with higher Hg exposure, but Se in hair was not correlated with higher Hg exposure.		"
Amiata Mt.	8 residents	0.35	Clemente (1977)
Iraq	175 rural and urban residents	(0.18-4.0)3.68, 3.15 med.	Al-Shahristani (1976)

(Continued)

TABLE A-16. SELENIUM IN HUMAN HAIR (Continued)

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
New Zealand Hastings	33 "normal" elementary school boys	(0.4-12.2)0.53	Bate & Dyer (1965)
Napier	33 "normal" elementary school boys	(0.4-0.9)0.69	"
Country Unspecified		(0.5-3.0)	Quittner et al. (1970)

TABLE A-17. SELENIUM IN HUMAN NAILS

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
Country Unspecified	Organic selenosis occurs in seleniferous areas. The nails of affected persons contain	(8.0-30.0)	Oelschlager (1970)

TABLE A-18. TIN IN HUMAN HAIR

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
New York	Sn in scalp hair of children only was correlated with environmental exposure gradients		Creason et al. (1975)
United States	Military academy and university students' scalp hair	1.0	Gordus et al. (1974)

TABLE A-19. VANADIUM IN HUMAN HAIR

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
New York	V in scalp hair in adults and children was significantly correlated with environmental exposure gradients		Creason et al. (1975)
New Hampshire	Female, age 3 yrs., blonde	0.0	Schroeder et al. (1963)
" "	Female, age 40, brown	2.59	"
" "	Female, age 65, red	2.71	"
United States	42 young males in Navy	means 0.032	Gordus et al. (1974)
" "	42 young males 5 mos. later	0.025	"
" "	42 young males 17 mos. later	0.021	"
" "	122 young males in Navy	medians 0.026	"
" "	78 young males 5 mos. later	0.024	"
" "	64 young males 17 mos. later	0.02	"
" "	54 young males in Air Force	0.041	"
" "	12 females, 1800-1899	0.009	"
" "	25 females, 1900-1930	0.006	"
Michigan	12 males, washed hair 2 x/mo.	0.036	Gordus et al. (1975)
"	12 males, washed hair 20 x/mo.	0.094	"
"	41 females, age 18-22 yrs. 1972	0.054	"
United States	27 females, age 12-40 yrs., 1910-1935	0.016	"
" "	11 females, age 12-40 yrs., 1890-1910	0.020	"

(Continued)

TABLE A-19. VANDIUM IN HUMAN HAIR (Continued)

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
United States	10 females, age 12-40 yrs., before 1890	0.014	Gordus et al. (1975)
	Preliminary data show a significant increase of V in hair of females age 12-40 years from before 1890 to the present.		"
	V lowers cystine content of hair, but there is normally much variation so nail cystine was used for determining V levels		Hudson (1964)
Venezuela	11 Amazonian indians	(0.03-0.7)0.23 med. 0.14	Perkons (1977)
Japan	45 rural residents	(0.004-0.093)0.03± S.D. 0.02 median 0.034 geom. mean 0.023	Ohmori et al.

TABLE A-20. VANADIUM IN HUMAN NAILS

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
	Vanadium at very low concentration decreases cystine content of fingernails (at 1 ppm/g of tissue)		Stokinger (1963)
Colorado	850 fingernail specimens were analyzed for cystine value in workers with carnotite ore, ammonium metavanadate, and oil industry workers		Mountain et al. (1955)
Peru	Workers processing patronite ore and in contact with vanadium pentoxide. The average nail cystine content of each vanadium-exposed group was consistently lower than its corresponding control group, and ranged from 8.2 to 9.6% cystine		"
	As the urinary V is increased, the nail cystine decreased		"
North America	Normal cystine of white males was 10.0%		"
	Nail cystine was used for determining V levels		Hudson (1964)
New Guinea	50 fathers, age 46±8 yrs. toenails	0.04±.D. 0.05	Masironi et al.(1976)
	" " " " "	median 0.02	
	" " " " "	geom. mean 0.02	
	" " " " "	geom. dev. 3.53	
" "	50 mothers, age 41±8 yrs.	0.07±S.D. 0.07	"
	" " " " "	median 0.05	
	" " " " "	geom. mean 0.04	
	" " " " "	geom. dev. 3.61	
" "	34 male teenagers, age 15±2 yrs.	0.12±S.D. 0.14 median 0.05	"

(Continued)

TABLE A-20. VANADIUM IN HUMAN NAILS (Continued)

Locality	No. & types of persons & special conditions	Analysis - PPM	Authority
New Guinea	23 female teenagers, age 15 yrs.	0.10±S.D. 0.10 median 0.07	Masironi et al. (1976)
" "	60 parents [drinking water Ca (1.2-3.2)2.4] toenails	(0.004-0.205)0.023	Masironi et al. (1976)
" "	20 parents [drinking water Ca (7.2-15.3)9.6]toenails	(0.007-0.029)0.036	"
" "	32 teenagers [drinking water Ca 2.4] toenails	(0.006-0.416)0.05	"
" "	20 teenagers [drinking water Ca 9.6] toenails	(0.012-0.625)0.083	"
	Drinking water with lower Ca had higher blood pressures		"
	There is a significant decrease in V toenails of parents vs. children. It was concluded that V in toenails reflects V in diet and not soil contamination of toenails, so scraping of toenails effectively removed contamination.		"

APPENDIX B

COMPILATION OF REFERENCE DATA ON HAIR, FUR, NAILS, CLAWS, AND HOOFS IN OTHER MAMMALS

This review of world literature is intended to be comprehensive, but not complete or exhaustive in coverage.

The tissues selected are the hair, fur, or pelt, and the appendages on the feet--nails from fingers and toes, claws from feet and flippers, and hoofs from ungulate feet.

There are relatively limited data on toxic trace elements in these tissues in mammals other than humans.

The data show that animal hair and fur are meaningful and representative tissues for biological monitoring and can be used for correlation with environmental gradients and disease correlated with excesses and deficiencies.

TABLE B-1. ANTIMONY IN ANIMAL HAIR

Species	Locality & Special Conditions	Analysis - PPM	Authority
Pronghorn antelope *Antilocapra americana*	Idaho	(0.4-0.97)0.86	Huckabee et al. (1972)
Coyote *Canis latrans*	Wyoming, 19 specimens	(0.09-1.8)0.67	"
Elk *Cervus canadensis*	Idaho	(0.9-13.0)4.2	"
Red-backed vole *Clethrionymys gapperi*	Wyoming	(0.1-0.6)0.3	"
Chipmunk *Eutamias sp.*	Wyoming	1.8	"
Vole *Microtus longicaudus*	Idaho	2.4	"
Mountain vole *Microtus montanus*	Wyoming	1.9	"
Meadow vole *Microtus pennsylvanicus*	Wyoming	1.3	"
Richardsons vole *Microtus richardsoni*	Wyoming	0.7	"
Mule deer *Odocoileus hemionus*	Idaho	(0.06-12.0)4.2	"
Mountain goat *Oreamnus americanus*	Idaho	0.28-0.29	"
Bighorn sheep *Ovis canadensis*	Wyoming	1.0	"
Shrew *Sorex vagrans*	Wyoming	(0.3-2.5)1.14	"
Mouse *Zapus princeps*	Wyoming	0	"
" "	Idaho	0.6	"

TABLE B-2. ARSENIC IN ANIMAL HAIR

Species	Locality & Special Conditions	Analysis - PPM	Authority
Cow *Bos bovis*	Washington; 10 dairy cattle 10-13 mi. downwind from Cu smelter	(3.7-19.0)8.9	Orheim et al. (1974)
" "	10 dairy cattle 37 mi. from Cu smelter (controls)	(0.13-0.84)0.46	"
" "	The data from hair indicates a twenty-fold increase in As. Data from blood and milk were low but showed double the increase over control.		"
Horse *Equus caballus*	Montana, 39 horses, manes	(0-7.5)	Lewis (1972)
" "	Montana, SSE of smelter 1.0 miles	Ave. 4.2	"
" "	Montana, N of smelter 1.0 miles	3.9	"
" "	Montana, E of smelter 2.9 miles	0.3	"
" "	Montana, SE of smelter 5.3 miles	0.3	"
" "	All other sites	0	"
Rabbit *Oryctolagus Cuniculus*	Switzerland, Feeding As produced local pigmentation in fur		Robert & Zürcher (1950)
" "	Rabbits 1 km from power plant had high accumulation of As in fur		Bencko (1970)
" "	13 rabbits exposed had As in hair and claws		Bencko et al. (1971)
Sheep *Ovis aries*	1.4 mg/kg As fed daily, As found in wool		Lancaster et al. (1971)
Rat *Rattus rattus*	Radioarsenic accumulated in hair		Strain & Pories (1966)

TABLE B-3. CADMIUM IN ANIMAL HAIR

Species	Locality & Special Conditions	Analysis - PPM	Authority
Moose *Alces alces gigas*	Alaska, 608 moose Cd was two times higher in July to October than November to June over a 3-year period.	(0.2-1.6)0.8	Flynn et al.(1975)
Cow *Bos bovis*	Missouri, farm animals exposed to Cd from lead smelter and trucking Pb concentrate		Dorn et al. (1974)
" "	Missouri, 4 exposed cattle on test farm:		"
	fall	1.29	
	winter	1.74	
	spring	2.8	
	summer	0.67	
" "	Missouri, 4 unexposed cattle on control farm:		"
	fall	0.06	
	winter	0.13	
	spring	0.05	
	summer	0.04	
" "	Cd in cattle hair in terminal summer sample was 12x higher than control cattle hair		"
Goat *Capra hircus*	0.112% of oral dose of ^{109}Cd was in hair		Miller et al. (1968)
" "	1.88% of I.V. dose of ^{109}Cd was in hair		"

(Continued)

TABLE B-3. CADMIUM IN ANIMAL HAIR (Continued)

Species	Locality & Special Conditions	Analysis - PPM	Authority
Horse Equus caballus	Montana, 39 horses, manes	(0.2-9.6)	Lewis (1972)
" "	Montana, NE of smelter 2.9 miles	9.0	"
Horse Equus caballus	Montana, E of smelter 2.6 miles	2.9	Lewis (1972)
" "	Montana, SSE of smelter 1.0 miles	2.4	"
" "	Montana, NW of smelter 1.4 miles	2.2	"
" "	Montana, N of smelter 1.0 miles	2.2	"
" "	Montana, W of smelter 3.0 miles	1.7	"
" "	Montana, E of smelter 2.9 miles	1.4	"
" "	Montana, NNW of smelter 1.9 miles	1.3	"
" "	Montana, WNW of smelter 7.6 miles	1.3	"
" "	Montana, E of smelter 4.7 miles	1.0	"
" "	Proximity of stacks of the smelter correlates with increased levels of Cd in horse manes and are consistent with Cd in soil and pasture grass		"
Mouse Mus musculus	44 days after injection of Cd	0.00011±0.00005	Nordberg & Nishiyama (1972)
" "	112 days after injection of Cd	0.00007±0.000033	"

TABLE B-4. CHROMIUM IN ANIMAL HAIR

Species	Locality & Special Conditions	Analysis - PPM	Authority
Pronghorn antelope *Antilocapra americana*	Idaho, 30 with Cr.	(1.9-640.0)	Huckabee et al. (1972)
" "	Wyoming, 7 with Cr.	(0.3-130.0)	"
Coyote *Canis latrans*	Wyoming, 15 of 19 with Cr	(0.7-12.0)	"
Elk *Cervus canadensis*	Idaho, 15 with Cr	(1.9-570.0)	"
Porcupine *Erethizon dorsatum*	Wyoming, hair	0.9	"
" "	Wyoming, quills	0.8	"
Chipmunk *Eutamias sp.*	Wyoming	29.1	"
Vole *Microtus longicaudus*	Idaho	1.7	"
Mountain vole *Microtus montanus*	Wyoming, 16	(4.7-180.0)	"
Meadow vole *Microtus pennsylvanicus*	Wyoming, 2 of 14 with Cr	(5.6-8.2)	"
Richardson's vole *Microtus richardsoni*	Wyoming	10.0	"
Mule deer *Odocoileus hemionus*	Idaho, 9 of 11 with Cr	(13.0-630.0)	"
Mountain goat *Oreamnus americanus*	Idaho, 2	(4.0-5.5)	"
Bighorn sheep *Ovis canadensis*	Wyoming, 1	0	"

(Continued)

TABLE B-4. CHROMIUM IN ANIMAL HAIR (Continued)

Species	Locality & Special Conditions	Analysis - PPM	Authority
Rat Rattus rattus	^{51}Cr is retained in rat hair		Strain et al. (1964)
Cotton rat Sigmodon hispidus	Tennessee, control, pelt	0.092±S.E. 0.007	Taylor et al. (1975)
" "	Tennessee, exposed to drift from cooling tower, pelt	1.056±S.E. 0.133	"
" "	Tennessee, control, hair	0.395±S.E. 0.021	"
" "	Tennessee, exposed to drift, hair	4.397±S.E. 0.555	"
" "	There was a 10 fold increase in Cr in both pelt and hair when rats ate vegetation with high levels of Cr.		"
" "	Tennessee, 100-130 m from source, pelt	(0.93-1.2)	"
" "	Tennessee, 100-130 m from source, hair	(3.9-4.8)	"
Shrew Sorex vagrans	Wyoming, 1 of 10 with Cr	15.0	Huckabee et al. (1972)
Western jumping mouse Zapus princeps	Wyoming, 3	(23.0-45.0)	"

TABLE B-5. COBALT IN ANIMAL HAIR

Species	Locality & Special Conditions	Analysis - PPM	Authority
Cow *Bos bovis*	Germany, Dietary supplement of Co significantly increased the level of Co in dairy cow hair in 112 days.		Anke (1966)
Rat *Rattus rattus*	^{58}Co was taken up and accumulated		Strain et al. (1964)
Mammalian hair		15.0	Bowen (1966)

TABLE B-6. COPPER IN ANIMAL HAIR

Species	Locality & Special Conditions	Analysis - PPM	Authority
Cow *Bos bovis*	United States (Missouri) 4 cattle exposed to lead smelter:		Dorn et al. (1974)
" "	fall	8.26	"
" "	winter	7.76	"
" "	spring	6.94	"
" "	summer	7.99	"
" "	4 cattle, controls, unexposed:		
" "	fall	7.25	"
" "	winter	7.84	"
" "	spring	6.81	"
" "	summer	7.41	"
" "	Sum of squares test showed no significant difference of Cu levels in hair of exposed and control cattle.		"
" "	Belgium, 536 cattle sampled 3 x/yr., but sampling method was too uncertain for diagnosis of Cu deficiency.		Chauvaux et al. (1965)
" "	East Germany, Dietary supplement of Cu significantly increased the level of Cu in dairy cow hair in 112 days.		Anke (1966)
" "	East Germany, Cu level in hair after extraction by diethyl ether and hot water did not change Cu level.		"

(Continued)

TABLE B-6. COPPER IN ANIMAL HAIR (Continued)

Species	Locality & Special Conditions	Analysis - PPM	Authority
Guinea pig Cavia porcellus	3 black	23.0±2.0	Kikkawa et al. (1958)
Guinea pig Cavia porcellus	3 white	23.7±2.0	"
" "	3 black piebald	19.7±9.2	"
" "	3 white piebald	15.2±4.7	"
" "	No significant differences in Cu content and hair color		"
Mouse Mus musculus	6 black	17.7±2.3	"
" "	5 white	11.3±1.1	"
" "	Difference not significant		"
Rabbit Oryctolagus cuniculus	11 black	17.4±2.1	"
" "	11 white	18.6±2.4	"
" "	Difference not significant		"
Pig Sus scrofa	4 black	17.1±1.9	"
" "	4 white	17.6±0.9	"
" "	Difference not significant		"

TABLE B-7. COPPER IN ANIMAL HOOFS

Species	Locality & Special Conditions	Analysis - PPM	Authority
Horse *Equus caballus*	Austria, 50 horses hoofs were examined for Cu. No differences were found in Cu content of younger and older parts of the hoof frog, and Cu was independent of sex, age, color of horse, or of hoof pigmentation.		Weiser et al. (1965)

TABLE B-8. LEAD IN ANIMAL HAIR

Species	Locality & Special Conditions	Analysis - PPM	Authority
Moose *Alces alces gigas*	Alaska, 608 moose	(3.5-10.0)6.0	Flynn et al. (1975)
" " "	(Pb in shoulder hair was low in Jan.-July, and high from August to Dec.)		"
Cow *Bos bovis*	Missouri, 4 exposed to Pb smelter and near to trucking of Pb concentrate:		Dorn et al. (1974)
" "	fall	94.13	"
" "	winter	87.5	"
" "	spring	96.5	"
" "	summer	66.0	"
" "	4 controls, unexposed farm:		
" "	fall	2.19	"
" "	winter	3.92	"
" "	spring	2.13	"
" "	summer	0.88	"
" "	Exposed cows had 75 times amount of Pb in hair compared with controls. Hair washed with soap and 10% SNOOP solution		"
" "	Correlation of hair and liver concentration of Pb in cattle with chronic lead poisoning was highly significant (P=<0.01)		Russel & Schöberl (1970)

(Continued)

TABLE B-8. LEAD IN ANIMAL HAIR (Continued)

Species	Locality & Special Conditions	Analysis - PPM	Authority
Guinea pig Cavia porcellus	Michigan, Detroit 10 breathed filtered air, pelt	0.12±S.D. 0.08	Smith et al. (1970)
" "	Michigan, Detroit 19 breathed city air ($2.5\ \mu g\ Pb/m^3$), pelt	0.18±0.11	"
Horse Equus caballus	Montana, 39 horses, manes:		Lewis (1972)
	Distance-smelter		
" "	NE 2.9 miles	35.0	"
" "	SE 2.6 miles	18.0	"
" "	NW 1.4 miles	12.0	"
" "	NNW 1.9 miles	10.0	"
" "	SSE 1.0 miles	8.0	"
" "	N 1.0 miles	7.4	"
" "	WNW 7.6 miles	7.1	"
" "	E 2.9 miles	5.2	"
" "	SE 5.3 miles	4.8	"
" "	W 3.0 miles	4.1	"
" "	WNW 2.3 miles	3.4	"
" "	E 4.7 miles	3.2	"
" "	NNW 2.3 miles	1.4	"

(Continued)

TABLE B-8. LEAD IN ANIMAL HAIR (Continued)

Species	Locality & Special Conditions	Analysis - PPM	Authority
Horse *Equus caballus*	Proximity to stacks of the lead smelters correlates with increased levels of lead in the manes of horses taking into account wind direction, residence time, and food sources. 50% of horses had lead levels 2-5 times greater than controls.		Lewis (1972)
White-tailed deer *Odocoilus virginianus*	Ohio, 8 deer, 6 with Pb	(0.0-14.4)5.92± S.D. 5.11 median 2.18	Lynch (1973)
Rabbit *Oryctolagus cuniculus*	Michigan, Detroit 12 breathed filtered air, pelt	0.19±S.D. 0.18	Smith et al. (1970)
"	Michigan, Detroit 14 breathed city air (2.5 $\mu g/m^3$), pelt	0.20±S.D. 0.13	"
"	Poland, ^{210}Pb in hair was 70% of ^{210}Pb in femurs 19 days after injection.		Jaworowski et al. (1966)
"	Poland, resting hair took up only a fraction of Pb taken up by growing hair.		"
Sheep *Ovis aries*	Sheep wool	10.0-30.0	Dankwortt (1942)
" "	Bulgaria, determined lead in sheep wool and cattle hair in areas with humans affected by nephritis.		Ivanov et al. (1962)

TABLE B-9. MERCURY IN ANIMAL HAIR

Species	Locality & Special Conditions	Analysis - PPM	Authority
Pronghorn antelope *Antilocapra americana*	Idaho, doe	0.01	Huckabee et al. (1972)
" "	Idaho, 5 wk. preterm fetus (from above)	0.3	"
" "	Idaho	(0.01-2.0)0.8	"
" "	Idaho & Wyoming, 44 tested, Hg found only in a herd near a chemical plant		"
Northern fur seal *Callorhinus ursinus*	Alaska, cows	4.87	Kim et al. (1974)
"	Alaska, new born pups	3.68	"
"	Alaska, 2 mo. old pups	5.36	"
Coyote *Canis latrans*	Wyoming, 19 samples	(0.008-2.8)0.57	Huckabee et al. (1972)
"	Wyoming, 85% had over 0.008 ppm in hair		"
Elk *Cervus canadensis*	Idaho, 10	(0.008-0.5)0.095	"
" "	40% had over 0.008 ppm		"
Red-backed vole *Clethrionymys gapperi*	Wyoming, 13	<0.008	"
Hood seal *Cystophora cristata*	Quebec, Magdalen Isl., 3 males	(2.64-7.63)5.06	Sergeant & Armstrong (1973)

(Continued)

TABLE B-9. MERCURY IN ANIMAL HAIR (Continued)

Species	Locality & Special Conditions	Analysis - PPM	Authority
Porcupine *Erethizon dorsatum*	Wyoming, hair	0.2	Huckabee et al. (1972)
"	Wyoming, quills	0.02	"
Chipmunk *Eutamias sp.*	Wyoming	0.3	"
Cat *Felis domesticus*	Japan, Minamata:		
	natural	39.8-52.0	Kitamura, Cited in Doi (1973)
" "	experimental	21.5-70.0	
	Yatsushiro City, along sea	46.6-51.0	"
" "	Shiranui-cho, along sea	9.8	"
" "	Amakusa-seto, along sea	117.0-117.5	"
" "	Ushifuka, along sea	17.6-33.1	"
Gray seal *Halichoerus grypus*	Nova Scotia, 3 females	Hg(1.8-16.0)7.0	Freeman & Horne (1974)
"	Nova Scotia, 2 females	Methyl Hg (0.24-2.5)1.4	"
"	Nova Scotia, 3 males	Hg(1.4-12.0)5.0	"
"	Nova Scotia, 3 males	Methyl Hg (0.2-2.8)1.12	"
Otter *Lutra canadensis*	Georgia, Piedmont, 3	(9.3-26.8)15.9	Cumbie (1975)
" "	Georgia, Lower coastal plain, 6	(15.8-67.9)37.6	"

(Continued)

TABLE B-9. MERCURY IN ANIMAL HAIR (Continued)

Species	Locality & Special Conditions	Analysis - PPM	Authority
Rhesus monkey *Macaca mulatta* & *Macaca iris*	Not fed methylmercury (control 0)	0.3	Ikeda & Tobe (1972)
" "	Fed methylmercury (0.01 mg/kg/day)	4.8	"
" "	Fed methylmercury (0.03 mg/kg/day)	19.0	"
Rhesus monkey *Macaca mulatta* & *Macaca iris*	Fed methylmercury (0.1 mg/kg/day)	44.0	"
" "	Fed methylmercury (0.3 mg/kg/day)	202.0	"
Vole *Microtus longicaudus*	Idaho	0.03	Huckabee et al. (1972)
Mountain vole *Microtus montanus*	Wyoming, non-Hg area	<0.008	"
" "	Wyoming, Hg-bearing area	<0.008-0.07	"
Meadow vole *Microtus pennsylvanicus*	Wyoming, non-Hg area	<0.008	"
" "	Wyoming, Hg-bearing area	0.08	"
Richardson's vole *Microtus richardsoni*	Wyoming, Hg-bearing area	0.09	"
Mink *Mustela vison*	Michigan, control, no Hg	1.13±0.08	Aulerich et al. (1974)

(Continued)

TABLE B-9. MERCURY IN ANIMAL HAIR (Continued)

Species	Locality & Special Conditions	Analysis - PPM	Authority
Mink *Mustela vison*	Fed 5 ppm Methyl-Hg 1 mo. (lethal)	1.22±0.12	Aulerich et al. (1972)
" "	Fed 10 ppm HgCl 5 mo. (no effect)	1.23	"
" "	Georgia, Piedmont, 5	(2.3-17.3)10.7	Cumbie (1975)
" "	Georgia, Lower coastal plain, 2	(5.9-15.4)10.7	"
Mule deer *Odocoileus hemionus*	Idaho, 11	<0.008	Huckabee et al. (1972)
Muskrat *Ondatra zibethica*	Canada	0.363-0.874	Jervis et al. (1970)
Mountain goat *Oreamnus americanus*	Idaho, 2	0.1	Huckabee et al. (1972)
Rabbit *Oryctolagus cuniculus*	Yugoslavia, in mercury area mine & plant	0.5	Byrne et al. (1971)
" "	In control area	0.3	"
" "	Yugoslavia, in contaminated area 9 wks.	293.3	Kosta et al. (1972)
Bighorn sheep *Ovis canadensis*	Wyoming	17.0(?)	Huckabee et al. (1972)
" "	Wyoming	<0.008	Huckabee et al. (1973)

(Continued)

TABLE B-9. MERCURY IN ANIMAL HAIR (Continued)

Species	Locality & Special Conditions	Analysis - PPM	Authority
Harp seal *Phoca groenlandica*	Canada, 6 mothers	(2.1-3.8)3.2±0.25	Freeman & Horne (1974)
" "	Canada, 10 pups	(0.63-3.6)1.7±0.26	"
Harbour seal *Phoca vitulina*	Nova Scotia, male	1.8	"
" "	Sable Isl., 8 male & female	(0.75-3.8)1.56	Sergeant & Armstrong (1973)
Shrew *Sorex vagrans*	Wyoming, 10	<0.008	Huckabee et al. (1972)
Black bear *Ursus americanus*	Idaho, 4 males	(0.11-0.275)0.18	Benson et al. (1974)
Western jumping mouse *Zapus princeps*	Wyoming, 3	(0.3-0.8)0.16	Huckabee et al. (1973)
California sea lion *Zalophus californianus*	Oregon coast, 2	(11.5-19.7)15.6±4.1	Buhler & Mate (1971)

TABLE B-10. MERCURY IN ANIMAL CLAWS AND HOOFS

Species	Locality & Special Conditions	Analysis - PPM	Authority
Bearded seal *Eringnathus barbatus*	Quebec, 4 males	(0.41-2.3)1.04	Freeman & Horne (1974)
"	Quebec, 5 females	(0.057-2.2)1.2	"
Gray seal *Halichoerus gryous*	Canada, 3 males	(4.4-9.8)7.7	"
"	Canada, 3 female	(3.2-8.6)6.7	"
Muskrat *Ondatra zibethica*	Canada	1.97	Jervis et al. (1970)
Harp seal *Phoca groenlandica*	Canada, 7 females	(2.2-5.4)3.7±0.41	Freeman & Horne (1974)
"	Canada, 10 pups	(0.8-3.6)1.8±0.27	"
"	Canada, 1 mother	8.6	"
"	Canada, 1 father	2.9	"
Ringed seal *Phoca hispida*	Quebec, 11 males	(0.77-3.6)1.79	"
" "	Quebec, 3 females	(1.4-4.2)2.3	"
Harbour seal *Phoca vitulinus*	Nova Scotia, 1 male	1.8	"

TABLE B-11. NICKEL IN ANIMAL HAIR

Species	Locality & Special Conditions	Analysis - PPM	Authority
Guinea pig *Cavia porcellus*	Black hair	trace	Kikkawa et al. (1958)
" "	White hair	trace	"
" "	Difference not significant		"
Rabbit *Oryctolagus cuniculus*	2, black hair	0.18±0.08	Kikkawa et al. (1958)
	2, white hair	1.70±0.41	"
" "	Difference not significant		"
Mammalian hair		6.0	Bowen (1966)

TABLE B-12. SELENIUM IN ANIMAL HAIR

Species	Locality & Special Conditions	Analysis - PPM	Authority
Pronghorn antelope Antilocapra americana	Idaho, 38 samples	(0.08-17.0)	Huckabee et al. (1972)
" "	Wyoming, 11 samples	(2.6-9.3)	"
" "	Wyoming, pregnant doe	4.5	"
" "	Wyoming, pre-term fetus	4.8	"
Cow Bos bovis	Alkali disease causes alepacia in cattle fed feed with 25-50 ppm Se		Radeleff (1964)
" "	Loss of hair with daily intake of 0.5 mg/kg Se		Muth & Binns (1964)
" "	Ontario, calves sick or dead from white muscle disease (Se deficiency) had low Se in hair	0.06-0.23	Hidiroglau et al. (1965)
" "	Ontario, no white muscle disease with hair of	0.25	"
" "	Ontario, Se content of cattle hair is helpful factor in diagnosing white muscle disease		"
Coyote Canis latrans	Wyoming, 19 specimens	0.8-13.0	Huckabee et al. (1972)
Elk Cervus canadensis	Idaho, 10, 7 had Se	(0.8-2.0)1.2	"
Red-backed vole Clethrionymys gapperi	Wyoming, 13 specimens	(0.1-0.9)0.5	"

(Continued)

TABLE B-12. SELINIUM IN ANIMAL HAIR (Continued)

Species	Locality & Special Conditions	Analysis - PPM	Authority
Horse *Equus caballus*	Horses lose hair with high Se		Rosenfeld & Beath (1964)
" "	Alkali disease is a form of selenosis causing alopecia. It may be caused by feeding 25-50 ppm Se in feed.		Radeleff (1964)
" "	Horses fed high Se diet develop malformed hoofs.		Rosenfeld & Beath (1964)
" "	S. Dakota, U.S. cavalry at Fort Randall had severe losses due to abnormal hoofs, due to high Se in pasture plants.		Harr & Muth (1962)
" "	Alkali disease is subacute form of organic selenosis, causing elongated weak and cracked hoofs, also caused by feeding feeds with 25-50 ppm Se		Radeleff (1964)
Porcupine *Erethizon dorsatum*	Wyoming, hair	1.0	Huckabee et al. (1972)
" "	Wyoming, quills	0.6	"
Chipmunk *Eutamias sp.*	Wyoming	3.4	Huckabee et al. (1972)
Cynomolgus monkey *Macaca fascicularis*	Canada, fed 10 ppm Na_2SeO_3:		Loew et al. (1975)
	40 days	2.35±0.45	"
	90 days	1.56±0.25	"
Vole *Microtus longicaudus*	Idaho	0.4	Huckabee et al. (1972)

(Continued)

TABLE B-12. SELENIUM IN ANIMAL HAIR (Continued)

Species	Locality & Special Conditions	Analysis - PPM	Authority
Mountain vole *Microtus montanus*	Wyoming	(1.2-1.6)1.4	Huckabee et al. (1972)
Meadow vole *Microtus pennsylvanicus*	Wyoming, 13 specimens	(0.2-27.0)5.4	"
Richardson's vole *Microtus richardsoni*	Wyoming	1.2	"
Mouse *Mus musculus*	Fed 3 ppm Se as Na selenite had poor coats of hair		Schroeder & Mitchener (1972)
Mule deer *Odocoilus hemonious*	Idaho, 11 sampls	(0.5-16.0)5.05	Huckabee et al. (1972)
Sheep *Ovis aries*	Alopecia caused by feed with 25-50 ppm Se		Radeleff (1964)
Shrew *Sorex vagrans*	Wyoming, 10 specimens	(2.1-68.0)12.09	Huckabee et al. (1972)
Pig *Sus scrofa*	United States	<1.0-1.2	Fuller et al. (1967)
Bighorn sheep *Ovis canadensis*	Wyoming	3.1	Huckabee et al. (19 72)
Rat *Rattus rattus*	Loss of hair with dietary exposure of 1 ppm Se and water containing 0.5 to 2.0 ppm Se		Muth & Binns (1964)
" "	United States, Selenate fed, age >600 days	3.91	Schroeder et al.(1970)

(Continued)

TABLE B-12. SELINUM IN ANIMAL HAIR (Continued)

Species	Locality & Special Conditions	Analysis - PPM	Authority
Rat Rattus rattus	United States, Selenate fed, age 994 days	9.92	Schroeder et al. (1970)
" "	United States, Selenite fed, age >600 days	3.81	"
" "	Control, no Se, age >600 days	0.6	"
" "	United States, As & Selenite fed, age 81 days	12.4	"
" "	United States, As & Selenite fed, age 81 days	9.67	"
" "	United States, As & Selenite fed, age 63 days	12.26	"
Western jumping mouse Zapus princeps	Wyoming	0	Huckabee et al. (1972)
" "	Idaho, mineralized area	1.6-2.4	"
"Animals"	Significant amounts of Se are found in the hoofs of poisoned animals		Heinreich & Kelsey (1955)
"Bats"	New York, 3 specimens	4.0	Schroeder et al. (1970)

TABLE B-13. SELENIUM IN ANIMAL NAILS AND HOOFS

Species	Locality & Special Conditions	Analysis - PPM	Authority
Cynomolgus monkey *Macaca fascicularis*	10 ppm of Se in diet caused loss of nails		Loew et al. (1975)

TABLE B-14. VANADIUM IN ANIMAL HAIR AND HOOFS

Species	Locality & Special Conditions	Analysis - PPM	Authority
Deer Odocoilus virginianus	New York, hoof	2.55	Schroeder et al. (1963)
Rat Rattus rattus	Vanadium pentoxide in diet of 25.0-1.000.0 ppm had lowered cystine in hair		Mountain et al. (1953)
" "	Coarse sparse hair resulted from high V in diet		"
" "	^{48}V was taken up and accumulated in the hair of laboratory animals		Strain et al. (1964)

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